DEPARTMENT OF THE ARMY

CORPS OF ENGINEERS

BEACH EROSION BOARD

OFFICE OF THE CHIEF OF ENGINEERS

ANNOTATED BIBLIOGRAPHY ON TSUNAMIS

TECHNICAL MEMORANDUM NO. 30

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FEBRUARY 1953

FOREWORD

This bibliography was prepared and annotated as a project of the Committee for the Study of Tsunamis, American Geophysical Union, by Mr. Marcial P. Cuellar. Mr. Cuellar, a graduate of the University of Chile, has been associated with the Board of Ports of Valparaiso, and the Department of Hydraulics of the Chilean Ministry of Public Works at Santiago. The bibliography was prepared during a period of study at the National Bureau of Standards under a training grant.

The international collaboration in this study of a truly international field of knowledge, as well as the importance of the contribution has led the Union to cooperate with the Beach Erosion Board as a leader in the study of wave phenomena, in the publication of this information for public use.

The membership of the Committee for the Study of Tsunamis at the time of preparation of this contribution were: Dr. C. A. Barnes, Dr. A. A. MacDonald, Mr. Walter B. Zerbe, Dr. Harry H. Hess, Dr. Walter H. Munk, Dr. Garbis H. Keulegan, and Dr. Martin A. Mason, (chairman).

This memorandum is published under authority of Public Law 166, 79th Congress, approved July 31, 1945.

1. King, P. P., Stokes, P.S., and Fitz Roy, R.

1836 Sketch of the surveying voyages of His Majesty's Ships "Adventure" and "Eagle," 1825-1836. Journal of the Royal Geographical Society of London, 6:319-331.

On 20 February 1835, a strong earthquake centering near Conception destroyed numerous towns in central Chile. About half an hour after the seismic shock a great tsunami swept the coasts of the epicentral region, causing great damage at Talcahuano and on Isla Santa Maria. The tsunami was felt along the whole coast of Chile and reached dangerous heights on the island of Juan Fernandez, which is located off the coast of Valparaiso, although the port of Valparaiso itself escaped damage. After the earthquake, upheavals of about 9 feet were observed at various places on Isla Santa Maria and evidence was found that similar topographical changes had taken place in the bed of the sea surrounding this island. Includes numerous narrations of eyewitnesses regarding the earthquake and tsunami.

2. Caldcleugh, A.

1836 An account of the great earthquake experienced in Chile on the 20th of February of 1835. Philosophical Transactions of the Royal Society of London, Part I, pp. 21-36. An abstract of this report was published in The Philosophical Magazine, London, 3d Ser., 8:148-150.

The Concepcion tsunami of February 1835 reached heights of 28 feet above high water level on the coast at Talcahuano. After the phenomenon it was observed that the island of Santa Maria had become permanently elevated at least 10 feet above its former position. Similar topographical changes were observed in the bed of the sea surrounding this island. These dislocations were ascertained very accurately by the observations of Capt. Fitz Roy (see No. 1). The tsunami was clearly perceptible on the island of Juan Fernandez (360 miles off the coast of central Chile) where it reached heights of 15 feet.

3. Parish, W.

1836 On the effects of the earthquake waves on the coasts of the Pacific. The Philosophical Magazine, London, 3d Ser. 8:181-186.

Contains much non-instrumental data regarding tsunamis recorded on the western coast of South America. The high frequency of tsunamis on these coasts and the urgency of geological studies are emphasized.

4. Mallet, R.

1852-1854 Catalog of recorded earthquakes from 1606 B.C. to A.D. 1850. Third Report on the Facts of Earthquake Phenonema, British Association for Advancement of Science. 22:1-176. 1852. 23:118-212. 1853. 24:2-326. 1854.

A very complete catalog of strong earthquakes recorded during the period 1606 B.C. to A.D. 1842, indicating those accompanied by tsunamis.

5. Bache, A. D.

1856 Notice of earthquake waves on the western coast of United States on the 23rd and 25th December, 1854. Report of the Superintendent of the U. S. Coast Survey for the year 1855, Washington, D. C. pp. 342-346. Also in the American Journal of Science and Arts, New Haven. 2nd Ser., 21:37-43.

On 23 and 25 December 1854 the tide gage at San Diego and San Francisco registered the arrival of the tsunami which accompanied the Ansei (Japan) earthquake. The marigrams showed that the first and most important group of waves had a mean period of 35 minutes and reached an average height of 0.45 foot. The velocity of propagation of the tsunami across the Pacific was found to be approximately 358 miles per hour, from which the mean oceanic depth along the propagation path was computed. Information regarding the destruction caused on the coasts of Japan by the earthquake and tsunami is also given.

6. Mallet, R.

1858 Report upon the facts and theory of earthquake phenomena. Report of the British Association for Advancement of Science. 28:124-131.

Marigrams recorded at U.S.A. stations during the Ansei tsunami of December 1854 (see No. 5) were analyzed, author concluding that the form of the waves recorded at San Francisco and San Diego agreed remarkably.

It is pointed out that tsunamis are caused, beyond question, by earthquakes or volcanic action on the sea bottom. It is added, however, that some abnormal tides observed were not preceded by seismic or volcanic disturbances and were probably produced by submarine landslides. These landslides would be caused by erosion, mainly by tidal action, of great submarine banks.

7. Hochstetter, F.

1868 Uber das Erdbeben in Peru am 13 August 1868 und die dadurch veranlassten Fluthwellen in Pacifischen Ocean. Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften, Vienna. 58(4):837-860. (In German)

A detailed account of the Arica earthquake and tsunami on 13 August 1868, which ruined several ports along the southern coast of Peru (now northern Chile), is given and narrations of various eyewitnesses are added. The tsunami, whose center was apparently located off the coast of Arica, was recorded at various tidal stations in the Pacific. From marigraphic data recorded at Newcastle (Australia), Chatham and Samoa Islands (South Pacific), Lyttelton (New Zealand), and Hawaii, the velocities of propagation of the tsunami through the Pacific were computed. Also, the propagation of the tsunami along the western coast of the Americas was determined by using non-instrumental data recorded in several ports on the coasts of Chile, Peru, and U.S. A.

8. Pinto, A.

1868 Fenomeno del mar ocurrido en nuestras costas del sur a consecurencia, segun parece, del gran terremoto que destruyo Arequipa el 13 de agosto de 1868. Anales de la Universidad de Chile, Santiago, 31:507-512. (In Spanish)

The Arica tsunami of August 1868, propagated southward, caused considerable damage on the ports of Talcahuano and Penco (central Chile), where a group of regular waves, whose periods fluctuated between 1 and $1\frac{1}{2}$ hours, was first recorded. The first group of waves was followed by a somewhat irregular motion lasting for several days. Several narrations of eyewitnesses, regarding mainly the structural damage caused by the tsunami on the coast of central Chile, are annexed.

9. Hochstetter, F.

1869 Die Erdbebenfluth im Pacifischen Ocean vom 13 bis 16 August 1868 und die mittleren Tiefen dieses Ocean. Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften, Vienna. 59:109-132. (In German)

Complementing the study made in a previous paper (see No. 7) on the propagation of the Arica tsunami of August 1868, additional information is given regarding the characteristics of the tidal disturbances produced by the tsunami at stations located in the Chincha Islands off Peru, the Hawaiian Islands, and at Sydney, Australia.

It was observed that the velocities of propagation of the waves through the Pacific agreed with those calculated by Bache (see No. 5) and with propagation of the normal tides. The mean oceanic depths along the paths of propagation of the waves were computed by applying the formulas of Airy and Russell.

10. Domeyko, I.

1869 Datos recogidos sobre el terremoto y las agitaciones del mar del 13 de agosto de 1868. Anales de la Universidad de Chile, Santiago de Chile. 32:1-43. (In Spanish)

Instrumental data recorded at several Chilean stations during the Arica earthquake and tsunami of August 1868 showed that the phenomenon was not accompanied by barometric or magnetic disturbances and that the climatlological conditions were unaltered by the seismic shock. An inspection of the epicentral area showed also that topographical dislocations or landslides did not take place during the phenomenon. An analysis of the damage distribution suggested that the earthquake was of the subcontinental type and its epicenter was located in the neighborhood of the Arequipa volcano.

11. Hochstetter, F.

1869 Die Erdbebenfluth im Pacifischen Ocean vom 13 bis 16 August 1868. Petermann's Geographische Mittheilungen, Gotha. 15:222-226. (In German)

Analyses made in previous papers (see Nos. 7 and 9) on the propagation through the Pacific of the Arica tsunami of August 1868 are summarized. Based on these studies, a general analysis of propagation of tsunamis through great oceanic depths is made, and the formulas for computing the velocities of propagation of seismic sea waves are discussed.

12. Proctor, R. A.

1869 Earthquake waves in the Pacific. Nature, London. 1:54-56.

The path of propagation through the Pacific of the Arica tsunami of August 1868 was determined by studying marigraphic data recorded at Hawaii, Japan, New Zealand, and Australia. From the velocities of propagation computed by Hochstetter (see Nos. 7, 9, and 11), the mean oceanic depths along the propagation paths of the tsunami were computed. It was found that these values agree fairly with those obtained from marigraphic data recorded during the Ansei tsunami of December 1854 (see No. 5).

13. Williamson, Juan D.

1869 Descripción de terremoto del 13 de agosto de 1868. Lima, Peru. (In Spanish)

Eyewitness description of the damage caused in the port of Iquique by the Arica tsunami of August 1868.

14. Gutierrez, M.

1870 Estadistica del horrible cataclismo del 13 de agosto de 1868. Valparaiso, Chile. (In Spanish)

A statistical compilation of data regarding the structural damage and casualties in ports located along the southern coast of Peru and northern coast of Chile caused by the Arica tsunami of August 1868. Numerous narrations of eyewitnesses concerning the heights reached by the waves are annexed.

15. Fonck, F.

1871 Las agitaciones oceanicas causadas en las costas del Pacifico por el terremoto del 13 de agosto, 1868. Anales de la Universidad de Chile, Santiago. 39:283-305. (In Spanish)

Complementing the works of Domeyko and Hochstetter on the propagation of the Arica tsunami of August 1868 (see Nos. 7, 9, 10, and 11) with additional data regarding the times of arrival and characteristics of the waves at stations located in New Zealand, Australia, Japan, Mexico, West Coast of U.S.A., and islands of the South Pacific.

Instrumental and eyewitness observations obtained at Chilean stations showed that the tsunami was not propagated parallel to the coast, perhaps because of the influence of the Peru Current, and that a tsunami of secondary magnitude was recorded in the epicentral region simultaneously with the seismic shock.

16.

Aug. 1877 The great earthquake on the coast of Peru. The Geographical Magazine, London, pp. 206-209.

On 9 May 1877 a severe earthquake, whose center was apparently located under the Andes, destroyed several cities in southern Peru (actually northern Chile). It was accompanied by a great tsunami which reached heights of 35 feet in Iquique and 75 feet in Arica. It is indicated that this tsunami reached greater heights in Arica than those recorded during the Arica tsunami of 1868. A catalog of destructive earthquakes on the west coast of South America (especially in Peru and Chile) is added.

17. Geinitz, E.

1877 Das Erdbeben von Iquique am 9 Mai, 1877 und die dadurch erzeugte Fluth im grossen Ocean. Petermann's Geographische Mittheilungen. 23(12):454-466. (In German)

Numerous narrations of eyewitnesses regarding the destruction caused on the north coast of Chile by the Iquique earthquake and tsunami of May 1877 were collected. These data, which were taken mainly from newspaper articles, are used for describing in detail these phenomena. By using marigraphic data recorded at stations located in Japan, New Zealand, and Hawaii, the velocities of propagation of this tsunami through the Pacific Ocean were computed. From these velocities the mean depths of the ocean along the propagation paths of the waves were computed by the formula $H = V^2/g$. It was observed that the values so obtained are substantially smaller than depths determined by soundings.

Note: Important corrections to the calculations indicated above were introduced by Dr. Geinitz in a later report (see No. 18).

18. Geinitz, E.

1878 Das Erdbeben von Iquique am 9 Mai 1877 und die durch dasselbe verursachte Erdbebenfluth im grossen Ocean. Nova Acta der Ksl. Leop.-Carol. Deutschen Akademie der Naturforscher, Halle. 40(9):385-444. (In German)

This second paper of Dr. Geinitz (see No. 17) on the propagation of the Iquique tsunami of May 1877 contains many additional observations and is in general more elaborate than the first one. Instrumental and eye-witness observations made at villages along the Chilean coast are compared with data recorded during the Arica tsunami of 1868. Several corrections are introduced, and computed depths at various points of the Pacific Ocean are considerably reduced. As a result of this second calculation, it is concluded (contrary to the first paper) that the mean depths of the ocean computed from the velocities of propagation of the Iquique tsunami are in accordance with those obtained by actual soundings.

19. Milne, J.

1880 The Peruvian earthquake of May 9, 1877. Transactions of the Seismological Society of Japan. 2:50-96.

By analyzing marigrams recorded at several tidal stations on the Pacific, the velocities of propagation of the Iquique tsunami of May 1877 were computed. From these values, by applying the formula $H = V^2/g$ the mean depths of the ocean along the propagation paths were determined. A comparison of such values with those calculated by Hochstetter (see Nos. 7, 9, and 11) showed that both values agreed closely when Japanese marigrams were considered, but disagreed substantially when based on marigrams recorded at Honolulu, Samoa, and Lyttelton. Based on the latter it was observed that the mean depths of the Pacific computed from the velocities of propagation of tsunamis did not agree with those obtained by actual soundings.

20. Walker, J. T.

1883 On the earthquake of the 31st December 1881. Proceedings of the Asiatic Society of Bengal, Calcutta, 3:60-62. Also in the General Report on the Operations of the Survey of India for 1881-1882.

The strong submarine earthquake of 31 December 1881 in the Bay of Bengal was accompanied by a destructive tsunami which was recorded by tidal stations on the west coast of the Bay of Bengal and on the island of Saugor. Copies of the recorded marigrams are given and a brief analysis of them is made. Some anomalies with regard to the propagation of the tsunami, due apparently to the presence of islands, are described.

21. Rogers, M. W.

1883 Memorandum on the earthquake of the 31st December 1881 and the great sea waves resulting therefrom, as shown on the diagrams of the tidal observations in the Bay of Bengal. Proceedings of the Asiatic Society of Bengal, Calcutta. 3:63-66.

The path of propagation of the Bay of Bengal tsunami of 1881 was determined by using marigrams recorded at Indian stations. From the marigraphic study it was concluded that the tsunami was proppagated with velocities between 2.9 to 6.2 miles per minute. It is indicated that these velocities are in general proportional to the oceanic depths of the traversed seas, but in some cases they were modified by meteorological phenomena (especially winds). These marigrams and some non-instrumental data were subsequently used to determine the tsunami center, which was believed to coincide with the epicenter of the earthquake preceding the tsunami.

22.

1883 The Java Upheaval. Nature, London, 28:443-444.
Also in Science. 2:469-470.

The volcanic eruptions on the island of Krakatoa Sunda Strait reached a crisis during 27 and 28 August 1883, when several explosions of great intensity were heard on the coasts of Java and Sumatra and a tsunami swept those coasts causing extraordinary damage. The tsunami reached heights of 30 meters in various ports near Krakatoa and was clearly perceptible in San Francisco Harbor. It is indicated that tsunamis are due to sudden disturbances of the ocean bed and are very frequent in the Pacific.

23.

1883 Scientific aspects of the Java catastrophe. Nature, London. 28:457-458

The area affected by the volcanic explosions on Krakatoa (August 1883) is highly volcanic, several catastrophes having been recorded there lately. However, according to the most reliable accounts, the outbreak of 27 August would appear to have been far more fatal to human life than either of its predecessors. The most potent agent of destruction in this case was the great tsunami produced by the earth shock accompanying the explosions. Outstanding topographical changes took place on the island and on the bed of its surrounding sea, where the appearance of new volcanic cones was observed.

24.

1883 The Java Eruption. Nature, London. 28:577.

The volcanic eruptions on Krakatoa produced sizeable subsidences and upheavals on the sea bottom of Sunda Strait. These displacements generated a tsunami which reached heights of 100 feet in some places and caused enormous damage on the southwest coast of Java and the south coast of Sumatra. In Batavia, according to accounts given by eyewitnesses, two groups of waves reaching heights of 17 feet were observed. The second group caused most of the destruction.

25. Baird, A. W.

1883 The great tidal wave. Nature, London. 28:626-627.

The tsunami caused by the volcanic eruptions at Krakatoa on August 1883 was recorded by tidal stations in India, South Africa, and Mauritius. The perturbations of the sea level observed by eyewitnesses at Port Louis (Mauritius) are described. The Royal Alfred Observatory at Mauritius recorded remarkable disturbances in the atmospheric pressure and important magnetic perturbations at the time of the tsunami.

26. Delisle, Dr.

1883 Les secousses de tremblement de terre a la Reunion et a Maurice comme consequence de l'eruption volcanique du detroit de la Sonde. Comptes Rendus des Seance de la Societe de Geographie de Paris. (15):524-526. (In French)

Eyewitness description of the tidal perturbations caused in Saint-Pierre (Reunion) and Mauritius by the Krakatoa disaster of August 1883.

27. de Lesseps, M.

1883 Propagation marine de la commotion du tremblement de terre de Java. Comptes Rendus de l'Academie des Sciences, Paris, 97:1172-1174. (In French)

On 27 August 1883, the marigraph at Colon (Atlantic coast of Panama) registered the arrival of eight oscillations with amplitudes between 0.3 and 0.4 meter. It is indicated that these waves corresponded to the tsunami generated by disturbances on the island of Krakatoa. The curious fact that the phenomenon was not recorded in Panama City (Pacific coast of Panama) is also pointed out. It is explained by taking into consideration that the waves propagated eastward from the island of Krakatoa quickly lost their energy by the presence of shallow seas, and that when they finally arrived in the Pacific they were already too small to cross the ocean.

28. de la Grye, M. Bouquet

1883 Sur La propagation des lames produites par l'eruption des volcans de Java. Comptes Rendus de l'Academie des Sciences, Paris. 97:1228-1230. (In French)

An attempt was made to determine by marigram analysis the path of propagation of the Krakatoa tsunami of August 1883. By studying marigrams recorded at several ports along the coast of France, it is concluded that the tsunami was propagated with a mean velocity of 305 miles per hour and was composed of a group of waves with a mean length of 375 miles.

29.

1883 The tidal waves of earthquakes. Engineering. 36:526.

Brief description is given of the propagation of the Krakatoa tsunami of 1883, based chiefly on the reports of de Lesseps and Bouquet de la Grye (see Nos. 27 and 28).

30. de la Croix, M. Erington, commentary by Daubree, M.

1883 Catastrophe du Krakatoa, vitesse de propagation des ondes liquides. Comptes Rendus de l'Academie des Sciences, Paris, 96:1575-1576. (In French)

The volcanic explosion of Krakatoa island on 27 August 1883 caused a gigantic tsunami which devastated the coasts of Java and Sumatra. By analyzing marigrams recorded at several places along the coast of Ceylon (3,000 kilometers from the island of Krakatoa) it was concluded that the waves were propagated with an average speed of 550 meters per second.

In a commentary annexed, M. Daubree points out that the velocities computed by de la Croix are probably exaggerated. Daubree suggests also that the tsunami was not caused by the explosion itself but by dislocations on the sea bottom of Sunda Strait produced by the eruptions.
Note: Later on (see No. 39) de la Croix corrected his computation of the velocities of propagation.

31. Metzger, E.

1884 Gleanings from the reports concerning the eruption of the Krakatoa. Nature, London. 29:240-244.

Abstracts of newspaper articles concerning the volcanic eruption on the island of Krakatoa (August 1883) are given. Most of these articles include narrations of eyewitnesses regarding the destruction caused in ports along the coast of Java and Sumatra by the tsunami which accompanied the Krakatoa eruptions. From these reports, the following conclusions regarding the tsunami were drawn: (a) the most destructive waves reached heights of 30 to 40 meters, (b) secondary tsunamis apparently took place before and after the main one.

32. Baird, A. W.

1884 Report on the tidal disturbances caused by the volcanic eruptions at Java, August 27 and 28, 1883 and the propagation of the supertidal waves. Proceedings of the Royal Society of London. 36:248-253.

From a study of marigrams recorded at Indian stations during the Krakatoa tsunami of August 1883, the following conclusions were obtained; (a) small tidal disturbances were recorded some time before the occurrence of the tsunami; (b) the primary effect observed in all the stations was a fall of the sea level (negative wave), (c) the waves reached a maximum amplitude on bays opening directly to the direction of propagation of the tsunami, (d) the time of occurrence of the final explosion, computed under the assumption that it coincided with the time of commencement of the tsunami, did not agree with that computed from the barometric waves which were propagated from Krakatoa at the time of the final explosion. An explanation of this divergence is advanced.

33. Walker, J. T.

1884 Earthquake disturbances of the tides on the coasts of India. Nature, London, 29:358-360.

The tidal stations in India had registered important tsunamis on the occasion of the Bay of Bengal earthquake (see Nos. 20 and 21) and during the volcanic eruptions on Krakatoa. By using these marigraphic data, the epicenter of the Bengal earthquake and the propagation of its tsunami along the coast of India were determined. The computed velocities of propagation were between 120 and 360 miles per hour and were found to be, in general, proportional to the depths of the traversed seas. Regarding the time of commencement of the Krakatoa tsunami, the computations made by Baird (see Nos. 25 and 32) using marigraphic data and those made by other investigators using barometric data are quoted.

34. Verbeek, M.

1884 Kort verslag over de uitbarsting van Krakatau op 26, 27 en 28 Augustus. Landsdrukkerij (Government Printing Office), Batavia, February 19, 1884. (In Dutch)

The eruptions of the various volcanoes on Krakatoa, which culminated in the great Krakatoa disaster of August 1883, are described. The final volcanic explosion produced the sudden immersion of a great part of the island. This extraordinary topographic dislocation resulted in the formation of an immense circular wave which caused severe damage on the coasts of Java and Sumatra. The marigraph at Port Elizabeth (South Africa) showed that the tsunami was propagated toward that place with a mean velocity of 566 kilometers per hour. About 5 months after the disaster a new volcanic explosion, accompanied by a relatively small tsunami, was recorded.
Note: Summaries in English and French of this report have been published by other magazines (see Nos. 36 and 37).

35. Forbes, H. O.

1884 The volcanic eruption of Krakatau. Proceedings of the Royal Geographical Society, London. 6(3):142-152.

A study of the geographic and volcanic features of the zone surrounding Krakatoa led the author to establish the following theory for explaining the explosions and destructive tsunami, which in March 1883 accompanied the eruptions of the volcano. The continuous eruption of this volcano either cleared out the old funnel into its submerged portion or found a fissure by subsidence or otherwise through which sea water was admitted to the heated interior of the volcano. The results was explosion after explosion in increasing violence as more material for generating steam found its way into the underground recesses. This phenonenon generated two kinds of waves:

(a) Waves generated by the sudden depression of sea level caused by the inrush of enormous quantities of sea water into the deep fissures, and

(b) Waves created by the ejected portions of the island falling into the sea.

The fact that the tsunami was unnoticed by ships cruising in the vicinity of the island could be explained by considering that the two kinds of waves neutralized each other on the spots where those vessels were at the time of the tsunami. It is finally stated that certainly the tsunami was not connected with any seismic movement of the sea bed.

36. Daubree, M.

1883 Observations extraites du rapport de M. Verbeek sur l'eruption de Krakatoa les 26, 27 et 28 aout 1883. Comptes Rendus de l'Academie des Sciences, Paris. 98:1019-1025. (In French)

Summary of the report by M. Verbeek given under No. 34 of this bibliography.

37. Verbeek, M.

1884 The Krakatoa eruption. Nature. 30:10-15.

Summary of the report given under No. 34 of this bibliography.

38. Boussinesq, M.

1884 Remarque relative a la vitesse de propagation de l'intumescence produite dans l'ocean Indien par l'eruption de Krakatoa. Comptes Rendus de l'Academie des Sciences, Paris. 98:1251-1252. (In French)

By using the Lagrange formula ($V = \sqrt{gH}$) the velocity of propagation to Port Elizabeth of the Krakatoa tsunami of 1883 was computed and it was found that this value agreed closely with that determinated by Verbeek (see No. 34) from marigraphic data.

39. de la Croix, M. Erington

1884 Eruption de Krakatoa, vitesse de propagation des ondes marines. Comptes Rendus de l'Academie des Sciences, Paris, 98:1324. (In French)

The computations presented in a previous paper (see No. 30) of the velocities of propagation of the Krakatoa tsunami of 1883 were corrected and a new value of 270 meters per second (instead of the previous one of 550 meters per second) for the mean velocity of propagation was obtained.

40. Boutelle, C. O.

1884 Water waves from Krakatoa. Science. 3:777.

Photographic copies of the marigrams recorded at Kodiak (Alaska) and Sausalito (San Francisco Bay) during the Krakatoa tsunami of 1883 are given. After a brief analysis of these marigrams it is concluded that more marigraphic data will be necessary before the path of propagation of this tsunami through the North Pacific can be established.

41. Verbeek, M.

1885 Krakatau. Batavia, Imprimerie de l'Etat. 396-461. (In French)

This book constitutes the best account of the Krakatoa disaster of August 1883 and includes most of the data given by other investigators in previous reports. Its chapter "Mouvement de la Mer" contains a very detailed exposition of the tsunami which accompanied the catastrophe, including among others the following studies:

(a) Determination of the cause and time of commencement of the tsunami through analysis of marigraphic and barometric data,

(b) Compilation of data concerning the heights reached by the waves and extent of the damage in ports located in the epicentral area,

(c) Compilation of data concerning the times of arrival of the tsunami at stations all over the world and computation of the velocities of propagation of the waves to such stations,

(d) Computation of the mean depths of the ocean along the paths of propagation of the waves, and

(e) Determination of the characteristics (lengths, period, and height) of the main waves and description of tsunamis of secondary magnitude, which preceded and followed the main tsunami.

Among the major conclusions brought out by this study are the following:

(a) The tsunami was caused by dislocation of the bed of the sea surrounding the island of Krakatoa,

(b) The tidal perturbations recorded at Colon (see No. 27) and West Coast of U.S.A. were not connected with the Krakatoa tsunami,

(c) The velocities of propagation of the tsunami agreed with those of propagation of the normal tides, and

(d) The dimensions of the waves and their velocities of propagation resemble those observed during tsunamis associated with earthquakes.

42. Watson, W.

1887 The "Umbria's" Wave. Nature, London. 36:508-509.

A description is given of the damage caused by a high wave which struck the steamer "Umbria" on 26 July 1887 while it was cruising in the North Atlantic. The author does not believe this wave was of seismic or volcanic origin.

43. Stromeyer, C. E.

1887 The "Umbria's" Wave. Nature, London. 37:151.

Regarding the large wave that struck the streamer "Umbria" (see No. 42), it is pointed out that a similar case was observed by the streamer "Faraday" on 14 February 1884. It is believed that these waves were generated by volcanic undersea disturbances in Faraday's Reef (North Atlantic).

44. Pereira, E. J.

1888 The great earthquake of Lisbon. Transactions of the Seismological Society of Japan. 12:5-19.

A very detailed accound of the structural damage caused by the Lisbon earthquake and tsunami of 1 November 1755 is given, including data regarding the meteorological conditions prevailing prior to and after the phenomenon. The tsunami, which swept the whole coast of Portugal, was especially severe on the port of Lisbon. The tidal disturbances produced by the tsunami were perceptible at Lisbon even a week after the disaster. A smaller earthquake, accompanied also by a tsunami, was recorded ten days after the big catastrophe.

45. Evans, F. J. and Wharton, W. L.

1888 On the seismic sea waves caused by the eruptions of Krakatoa, August 26th and 27th, 1883. Part III of "The Eruption of Krakatoa and Subsequent Phenomena" published by the Royal Society of London. pp.89-151.

An account is given of the destruction caused by the Krakatoa tsunami of August 1883, based mainly on the report of Verbeek (see No. 41), The appearance during the phenomenon of new islands and volcanic cones in Sunda Strait and the extraordinary topographical changes suffered by Krakatoa and adjacent islands showed that enormous displacements took place in the bed of the sea surrounding Krakatoa.

The tsunami, even though it was unnoticed by ships cruising in the neighborhood of Krakatoa, caused enormous destruction on the coasts of Java and Sumatra, where it reached heights of 50 feet. It was recorded at stations all over the world. A study of instrumental and eyewitness observations regarding the times of arrival and characteristics of the waves at stations all over the world showed that:

(a) The waves propagated eastward and southward from Krakatoa were perceptible only in the immediate neighborhood of the tsunami-center and

(b) The tidal disturbances recorded at New Zealand, Honolulu, and the West Coast of U. S.A. were not connected with the Krakatoa tsunami.

The marigraphic study also showed that the tsunami was composed of two kinds of waves:

(a) Short waves with irregular and relatively small periods, caused by masses of rocks and earth falling into the sea during the eruptions or by the undersea explosions, which were responsible for most of the damage, and

(b) Long waves with periods over one hour which were generated by the sea bed dislocations and constituted the tsunami itself as recorded by the marigraphs.

Since both kinds of waves were propagated with the same speed and were generated simultaneously, it was rather difficult to study them separately.

46. Stromeyer, C. E.

1895 Abnormal Atlantic Waves. Nature, London. 51:437-438

Complementing the information given in a previous paper (see No. 43) regarding tsunamis originated by volcanic disturbances at Faraday's Reef, the cases of eight streamers that were struck by similar waves while crossing the North Atlantic are cited. It is shown that at least seven of these waves may have originated at a common center (Faraday's Reef) and might therefore be due to submarine volcanic activity.

47. Milne, J.

1896 The great sea waves in Japan. The Geographical Journal, London. 8:157-160.

In view of the destructive Sanriku (northeast coast of Japan) tsunami of 17 June 1896 the high seismicity of the Tuscarora Deep (apparent center of the tsunami) is brought into consideration. A geological study of this area suggests that a submarine range of mountains is slowly growing upward, therefore often producing tectonic displacements of the sea bed. In proof of this theory, the works of Foster on submarine displacements occurring in the Mediterranean are quoted. The hypothesis that this tsunami was generated by a sudden fracture of the sea bottom is corroborated by the breakage of a submarine cable lying on the disturbed area.

48. Milne, J.

1896 The great seismic wave of Japan. Nature, London. 54:449-450

The Sanriku tsunami of 1896, which devastated numerous ports along the northeast coast of Japan, followed a relatively small earthquake. According to Prof. Milne, it originated from a sudden collapse of the submarine crater known as the Tuscarora Deep. Marigrams recorded at three Japanese stations are studied and the works of Milne regarding seismic dislocations of the sea bed are quoted. Finally, several previous destructive tsunamis are briefly described, leading to the conclusion that tsunamis have their origin in some distrubance occurring in the bed of the sea.

49. Davison, C.

1897 Note on an error in the method of determining the mean depth of the ocean from the velocity of seismic sea waves. The Philosophical Magazine, London. 43:33-36.

The mean oceanic depth along the propagation path of a tsunami, as computed by the formula $V = \sqrt{gH}$ (the velocity of tsunami propagation being determined from marigraphic data), is always smaller than that obtained by soundings, as can be observed from calculations made by Wharton for the case of the Krakatoa tsunami of 1883 (see No. 45) and by Geinitz and Milne for the case of the Iquique tsunami of 1877 (see Nos. 18 and 19). Both Wharton and Milne explain this discrepancy by taking into consideration the inaccuracy of the actual soundings of the deep sea. The author, assuming that the discrepancy is brought about by the incorrect use of the indicated formula, proposed a modified method for the case when the sea depth along the propagation path of the tsunani is a parabola.

50. Milne, J.

1897 On the sea waves and earthquakes of June 15, 1896 in North Japan. Second Report of the Committee on Seismological Investigation, British Association for Advancement of Science. pp. 153-159.

The times of arrival of the Sanriku tsunami of June 1896 at several ports along the northern coast of Japan are given and an attempt to locate the tsunami center is made. It is concluded that the tsunami was probably caused by a landslide in the Tuscarora Deep (about 130 miles from the northeast coast of Japan) and was as destructive as the Krakatoa tsunami of August 1883.

51. Milne, J.

1897 Sub-oceanic changes. The Geographical Journal, London, 10(2):129-146 and 10(3):259-289. This paper, slightly modified was published in the Second Report of the Committee on Seismological Investigation, British Association for Advancement of Science, pp. 181-206.

The idea that important submarine landslides and sea bed dislocations are caused by submarine seismic and volcanic action is advanced. That such displacements of the sea bottom had often taken place is proved by a study of fractures of undersea cables which were found to be buried for several miles. The magnitude of those dislocations indicates that some geological changes of the sea bed are rather large compared with those occurring upon land areas.

A list of recent cable breakings is given, suggesting that an investigation of seismicity of undersea regions could be developed by a statistical study of cable interruptions. The fact that tsunamis are frequent in undersea regions of high seismicity is cited as confirmation of the theory that submarine earthquakes are the main cause of tsunamis.

52. Suess, E.

1897 La face de la Terre. Armande Colin et Cie, Editeurs, Paris, Volume I, pp. 25-95. (In French) This book was published originally under the title "Antlitz der Erde" in German.

A thorough study of ancient records led the author to believe that the legend of the Deluge was based on the occurrence of a tsunami, which inundated part of Mesopotamia in pre-biblical times. In order to show that tsunamis can cause enormous destruction over great areas, the extent of the damage caused by several tsunamis occurring during the last century is described briefly. The biblical legend resembles descriptions found in Babylonian documents apparently written between 330 and 260 B.C. These manuscripts describe a large earthquake and tsunami which destroyed numerous cities in Chaldea. The earthquake was centered apparently in the Arabian Sea and was accompanied by extensive topographical changes.

53. Milne, J.

1898 Sub-oceanic changes in relation to earthquakes. Third Report of the Committee on Seismological Investigation, British Association for Advancement of Science, pp. 251-254.

Information given in a previous paper (see No. 51) regarding study of fractures of undersea cables as a means of investigation seismically active undersea regions is summarized. Additional data regarding recent cable interruptions are given and the correlation between tsunamis and earthquakes of submarine foci type is emphasized.

54. Milne, J.

1898 Earthquakes and other earth movements. Kegan, Trench, Trubner and Co., London Fourth Edition, Chapter IX.

Several destructive tsunamis are described briefly and non-instrumental data regarding height and propagation velocity of tsunamis are added. Various theories concerning the mechanism of tsunami generation are analyzed, with the conclusion that the greater number of tsunamis have been produced by earthquakes of submarine foci type, causing underwater landslides. Considering the effect of slope of the sea bottom upon the propagation of tsunamis, the author concludes that tsunamis cause destruction only in shallow bays. By applying the formula $V = \sqrt{gH}$ to marigraphic data obtained during important tsunamis, the mean depths of the ocean along their propagation paths were computed. These values were subsequently compared with actual depths obtained by soundings.

55. Polo, J. T.

1898-1899 Sinopsis de temblores y volcanes del Peru. Boletin de la Sociedad Geografica de Lima, Peru. 8:321-249, 8:388-416, and 9:15-95. (In Spanish)

A complete catalog of strong earthquakes recorded in Peru during the period 1550-1880. Separate descriptions of the Arica (1868) and Iquique (1877) tsunamis are included.

56. Davison, C.

1900 On the sea waves connected with the Japanese earthquake of June 15, 1896. The Philosphical Magazine, London, 50:579-583.

A map of the area affected by the Sanriku earthquake of June 1896 is given. The quake epicenter was located about 240 miles off the coast of Miyako. The propagation through the Pacific of the tsunami which accompanied this earthquake was studied by using marigrams recorded at Honolulu and San Francisco. The mean depth of the ocean along the path of propagation of the waves, computed by the formula $H = V^2/g$, was found to be substantially smaller than that obtained by soundings. The marigram recorded at Honolulu showed a group of 17 regular waves with an average period of 25.5 minutes, while that recorded at San Francisco showed 30 waves with an average period of 6 minutes.

57. Vidal-Gormaz, F.

1901 Terremoto del 13 de agosto a las 5 H.P.M. Algunos Naufragios Ocurridos en las Costas Chilenas, Santiago de Chile. pp. 378-382. (In Spanish)

The Arica tsunami of August 1868, which inundated numerous ports along the north coast of Chile, destroyed several vessels in the bays of Arica and Pisagua. The loss of these craft was due mainly to the irregular oscillations of the sea level caused by the tsunami in the bay. After the disaster several small boats were found lying on the beach at distances of more than 300 meters from the ocean.

58. Vidal-Gormaz, F.

1901 El gran temblor de tierra. Algunos Naufragios Ocurridos en las Costas Chilenas, Santiago de Chile. pp. 470-479. (In Spanish)

The Iquique earthquake of May 1877 was followed by a destructive tsunami which threw up on shore several vessels standing in the bays of Iquique and Arica. Narratives of survivors of the destroyed boats regarding the height and intensity of the waves are annexed.

59. Omori, F. and Sekiya, S.

1904 Material for the earthquake history of Japan. Shinsai Yobo Chosakai Hokoku (Reports of the Imperial Earthquake Investigation Committee). 46:1-606. (In Japanese)

A catalog listing more than 2,200 strong earthquakes recorded in Japan during the period 416-1866, indicating the earthquakes which were accompanied by tsunamis.

60. Goll, F.

1904 Die Erdbeben Chiles. Munchener Geographische Studien, Munchen. pp. 1-65. (In German).

A catalog of destructive earthquakes registered in Chile during the period 1570-1879, including descriptions of the tsunamis of Concepcion (1835), Arica (1868), and Iquique (1877). Studies of the seismicity and vulcanism of several Chilean zones are annexed.

61. Kikuchi, D.

1904 Recent seismological investigations in Japan. Tokyo Printing Company, Ltd., Tokyo. (especially pp. 22-26)

The geographical position of the epicenters of earthquakes which had generated important tsunamis in Japan during the last 12 centuries are analyzed. It is concluded that these tsunamis were caused exclusively by earthquakes of submarine foci. This fact would agree with Professor Omori's hypothesis that larger tsunamis are caused by submarine earthquakes of surface-foci type and that the tsunami intensity is inversely proportional to the depth of the earthquake foci.

62. Yoshida, Y., Honda, K. and Terada, T.

1904,1907
1908 On the secondary undulations of oceanic tides. Tokyo Sugaku-Butirigakkwai Kiji-Gaiyo (Proceedings of the Tokyo Physico-Mathematical Society), 2:222-232, and 4:79-88 Second Series. Also in Philosophical Magazine, London, 15:88-126 Sixth Series, and in Publications of the Imperial Earthquake Investigation Committee in Foreign Languages. 26:1-113.

With regard to the work of Prof. Omori regarding oscillation periods of secondary undulations into bays, the nature of the undulations in 50 Japanese bays along the coasts of the Pacific Ocean and Japan Sea were studied and their period systematically tabulated. Finally a formula for computing the period of the most prominent undulations into a bay was developed. In addition, some model experiments on different types of bays were carried out, verifying the Omori theory that the period of tsunami waves observed on a bay are nearly the same as those of the usual secondary undulations of that bay. This theory would be especially accurate when the origin of the tsunami is remote from the observing station. A further confirmation of this theory is obtained by a study of marigrams recorded during the Krakatoa tsunami of 1883. It was also observed that the periods of small tidal disturbances caused by cyclonic storms are nearly similar to those recorded at ordinary times and during strong tsunamis.

63. Omori, F.

1906 Note on the tidal waves caused by the great Krakatoa eruption of 1883. Tokyo Sugaku-Buturigakkwai Kiji-Gaiyo (Proceedings of the Tokyo Physico-Mathematical Society) 2(29):455-457.

The Krakatoa tsunami of August 1883 was due mainly to the sudden compression and expansion of the air around Krakatoa at the moment of the volcanic explosions. The dislocations of the sea bottom, seismic vibrations of the sea bed, and the enormous avalanche of rocks and earth falling into the sea contributed to the generation of the tsunami, but these factors were negligible compared with the effect caused on the water by quick change in the atmospheric pressure over the sea at the moment of the final explosion. This hypothesis is justified by showing the extraordinary variation of atmospheric pressure recorded by barometers located near Krakatoa.

64. Tarr, R. S. and Martin, L.

1906 Recent changes of level in the Yakutat Bay region. Bulletin of the Geological Society of America. 17:29-64.

In 1905 a party of the U. S. Geological Survey, making a geological study of the Yakutat Bay region (Alaska), found conclusive evidence of the earthquake and tsunami which devastated that area on September 1899. Physiographic evidence of recent uplifts (elevated beaches) and subsidence (submerged forests) on the land and of violent changes on the sea bed (new islands) were found. The greatest change of level computed on the land area was 47 feet. The recent occurrence of these displacements was confirmed by a study of plants and marine organisms. Equally conclusive was the evidence of a destructive tsunami. The area swept by the waves was studied and data regarding the height reached by the water and the energy of the waves were obtained.

65. R.D.O.

1906 The Valparaiso earthquake. The Geographical Journal, London. 28(4):386-387.

On 17 August 1906 a destructive earthquake, centering near the port of Valparaiso, destroyed several cities in central Chile. A few hours after the seismic shock, a tsunami unnoticed on the Chilean coast was registered at the Hawaiian Islands. The times at which the waves were recorded showed that they were connected with the Valparaiso earthquake. The tsunami would indicate a submarine origin of the earthquake but further studies will be necessary to determine if the disturbance of the sea bottom which gave rise to the tsunami was accompanied by any permanent change in the level of sea and land. The soundings taken in Valparaiso harbor have shown so far that dislocations did not take place in the bed of the bay. However, it appears that such changes occurred somewhere north of the bay, where the seismic fault was located.

66. Honda, K.

1906 On the velocity of sea waves through the Pacific. Tokyo Sugaku-Buturigakkwai Kizi (Proceedings of the Tokyo Mathematico-Physical Society). 3:165-169.

The velocities of propagation of several strong tsunamis which had travelled across the Pacific were computed by using marigrams recorded at Japanese and American stations. Several probable propagation paths were studied, that of minimum time being selected. The velocities of propagation were subsequently computed by the Lagrange formula $V = \sqrt{gH}$. When the values obtained by both methods were compared, it was found that:

(a) The velocities of different tsunamis agree fairly, but are always smaller than those computed by the Lagrange formula, and

(b) As regards velocities of the same tsunami to different stations, they increase slightly with the distance, even though the mean depth of the ocean remains nearly constant.

67. Omori, F.

1907 Notes on the Valparaiso and Aleutian earthquake of August 17, 1906. Bulletin of the Imperial Earthquake Investigation Committee, Tokyo. 1(2):75-113.

On 17 August 1906, almost simultaneously with the great Valparaiso earthquake, another important shock took place near the Aleutian archipelago. The Valparaiso earthquake was accompanied by a tsunami which, even though it was unnoticed on the Chilean coast (owing to the great depth of the ocean along the shore), was recorded by Japanese marigraphs. The velocities of propagation of this tsunami to tidal stations located in the U.S.A., Japan, and Hawaii were computed by using marigraphic data and by applying the formula $V = \sqrt{gH}$. The results given by both methods agree fairly in the case of Japanese and Hawaiian stations, but substantial discrepancies were observed when marigrams recorded at U.S.A. were used. These discrepancies probably were due to errors of the assumed wave paths.

68. Omori, F.

1907 Note on the eruption of the Unsen-dake in the 4th year of Kansei. Tokyo Sugaku-Buturigakkwai Kizi (Proceedings of the Tokyo Mathematico-Physical Society), Second series, 4:32-34. Also in the Bulletin of the Imperial Earthquake Investigation Committee. 1(3):142-144.

The eruptions of the Unsen-dake volcano (Shimabara Peninsula, Japan) culminated in a strong earthquake on 21 May 1792. As a result of this earthquake a part of the Mae-yama (mountain reaching 876 meters above sea level) slid down, producing an immense avalanche of rocks and earth which descended into the Ariaka Wan. This avalanche produced a tsunami which reached a height of 30 feet in some places and devastated various villages along the eastern coast of Shimabara and Ariaka Wan. It is indicated that a similar phenomenon took place on 2 April 1868 in Hawaii during the eruption of Mauna Loa.

69. Hobbs, W. H.

1907 Origin of ocean basins in the light of the new seismology. Bulletin of the Geological Society of America. 18:241-246.

A study of the geographical distribution of the centers of the largest recorded tsunamis has shown that such centers do not coincide with the geographical location of active or extinct volcanoes. Therefore, it is believed that tsunamis would be due to earthquakes of submarine foci type. It is suggested that the seismically active zones within the undersea regions (habitual tsunami areas) could be located through a study of fractures of transoceanic cables (see No. 51). A preliminary study of undersea regions indicates that the North Atlantic basin is an area of very low seismicity and therefore immune to tsunamis. Finally, it is pointed out that the dislocations of the sea bottom would be enormous compared with those of land areas.

70. de Ballore, Montessus

1907 La Science seismologique. Librairie Armand Colier, Paris. Chapter VII. (In French)

By a comparative study of the geographical distribution of the epicenters of submarine earthquakes, undersea volcanoes, and tsunami centers, it was concluded that:

(a) Tsunamis only rarely accompany submarine volcanic disturbances,

(b) Most of the tsunamis studied had followed a short time after the occurrence of an earthquake of submarine foci type, and

(c) Strong submarine earthquakes do not always produce tsunamis. The previous conclusions confirm the hypothesis that tsunamis have their origin in tectonic displacements of the sea bed and that such dislocations are caused by seismic action. For studying the laws of tsunami propagation, marigrams recorded during the tsunamis of Arica (1868) and Krakatoa (1883) were analyzed.

71. R.D.O.

1909 The Italian earthquake. Nature, London. 79:287-288.

Much non-instrumental data regarding the Messina-Calabria (Italy) earthquake and tsunami of 28 December 1908 was collected. These data showed that the earthquake was polycentric and that the greatest foci were submarine. It is believed that these numerous centers would be responsible for the extraordinary displacements of the sea bed which produced the tsunami. The appearance during the earthquake of numerous visible land fissures on the coasts of Calabria and Sicily indicated to some extent the magnitude of the underwater dislocations.

72. Ricco, A.

1909 Terremoto del Messinese e della Calabria al 28 dicembre 1908. Bollettino della Accademia Gioenia di Science Naturali, Catania. pp. 3-7. (In Italian)

The Messina-Calabria tsunami, which devastated numerous ports along the coasts of Sicily and Calabria on 28 December 1908, reached a height of 4 meters in Messina Strait and a maximum of 6 meters in some bays along the strait. By use of seismograms recorded during the earthquake, which preceded the tsunami, and the damage distribution on the affected area, valuable information for tracing the isoseismal lines was obtained.

73. Lacroix, M. A.

1909. Resume de quelques observations de M. A. Ricco sur le tremblement de terre de Sicile et de Calabre, Comptes Rendus de l'Academie des Sciences, Paris. 148:207-209. (In French)

By using data recorded by Prof. Ricco (see No. 72), the earthquake and tsunami which devastated Calabria and Sicily on December 1908 are discussed.

74. Irving, A.

1909 The Italian earthquake, Nature, London. 79:428-429.

A geological study of the epicentral area of the Messina-Calabria tsunami of December 1908 showed that the seismic fault which produced the earthquake preceding the tsunami started from the north coast of Calabria and followed south down to the entrance of Messina Strait, where it broke into two branches extending through the entire length of the strait. This bifurcation of the fault would explain the dual tsunami which destroyed the ports of Messina and Reggio, Located on different sides of the strait. The study also showed that the sea bed in the eipicentral area presents the same geological and geophysical characteristics as the north-east coast of Japan where tsunamis are frequent. The predominant displacements were upheavals of the sea bottom, which were confirmed by the nature of the external fissuring of the ground observed on the coasts of Calabria and Sicily.

75. Ricco, A.

1909 Il terremoto e maremoto del 28 dicembre 1908. Bollettino della Accademia Gioenia de Scienze Naturali, Catania. pp. 10-17. (In Italian)

The information given in a previous paper (see No. 72) regarding the Calabria-Messina tsunami of December 1908 is supplemented and the decrease of height of the tsunami along its propagation path is studied. By using marigrams recorded at Malta the velocity of propagation, length and height of the main waves were computed. The theoretical upheaval of the sea bottom necessary for producing a tsunami of such destructiveness was also computed. The value thus determined was of such magnitude that displacements of the sea bed could not be accepted as the main cause of this tsunami.

76. Platania, G.

1909 I fenomeni marittimi che accompagnarono il terremoto di Messina. Rivista Geografica Italiana e Bollettino della Societa di Studi Geografici e Coloniali, Firenze. 16:154-161. (In Italian)

This paper is a summary of an article regarding the Messina-Calabria tsunami of December 1908 which was published later in the Bollettino della Societa Sismologica Italiana (see No. 79).

77. Martinelli, G.

1909 Osservazioni preliminari sul terremoto Calabro-Messinese del mattino del 28 dicembre 1908. Bollettino Bimensual della Societa Meteorologica Italiana. Vol. 28, Nos. 1-3. (In Italian)

By a detailed study of the times of arrival and heights reached by the waves at different ports along the coasts of Sicily and Calabria during the Calabria-Messina tsunami of December 1908, the path of propagation of the tsunami was determined. The decrease of height of the tsunami along its propagation path was also studied.

78.

1909 The Italian earthquake of December 28, 1908. Nature, London. 80:445.

This paper describes briefly the Calabria-Messina earthquake and tsunami of December 1908 with data taken from the reports of Martinelli and Platania (see Nos. 76 and 77).

79. Platania, G.

1909 Il maremoto della stretto di Messina del 28 dicembre 1908. Bolletino della Societa Sismologica Italiana, Modena. 13(7 & 8):369-458. (In Italian)

A very complete description of the structural damage caused by the Messina-Calabria tsunami of December 1908 on ports along the coasts of Sicily, Calabria, and the Eolis Archipelago is given. On the basis of non-instrumental data, obtained mainly by questionnaires of eyewitnesses, it is shown that the tsunami was produced by strong displacements of the sea bed. As a confirmation of this conclusion the breakage of four transoceanic cables lying on the epicentral area is mentioned. The maximum height reached by the tsunami in the immediate neighborhood of the coast was about 7 meters and the wave periods varied between 10 and 15 minutes.

80. Omori, F.

1909 Preliminary report on the Messina-Reggio earthquake of December 28, 1908. Bulletin of the Imperial Earthquake Investigation Committee, Tokyo. 3(2):37-45.

By a careful investigation of the traces left by the Messina-Calabria tsunami of December 1908, the directions of propagation of the waves at different ports on both sides of the Messina Strait were computed. With these data the center and path of propagation of the tsunami were computed, it being concluded that the tsunami probably had two centers and that only the smaller one seemed to coincide with the location of the earthquake epicenter. It is finally pointed out that the tsunami was caused by great dislocations of the sea bed in the Strait of Messina.

81. Baratta, M.

[illegible] La catastrofe sismica Calabro-Messinese. Relazione alla Societa Geografica Italiana, Roma. (In Italian)

A very complete report on the structural damage produced by the Messina-Calabria tsunami of December 1908 on ports along the coasts of Sicily, Calabria, Isole Eolie, and adjacent islands in the Mediterranean is given. The report includes data regarding heights reached by the tsunami, times of arrival, the meteorological conditions prior to and after the phenomenon. A brief description of previous tsunamis which had occurred along the southern coast of Calabria is also given. From a comparative study of these tsunamis it is concluded that most of them were produced by earthquakes with submarine foci, but that at least one of the smallest tsunamis recorded (16 November 1894) was generated by a quake centering entirely on land.

82. de Sousa, F. L. Pereira

1911 La raz de maree du grand tremblement de terre de 1755 en Portugal. Comptes Rendus de l'academie des Sciences, Paris. 152:1129-1131. (In French)

The destruction caused by the Lisbon earthquake and tsunami of 1755 on the coasts of Portugal and the Azores is described. This description includes non-instrumental data regarding structural damage, heights reached by the waves on the coast, and a study of the topographical features of the epicentral area. The direction of propagation of the wave suggests that the tsunami center lay at the entrance of the Gulf of Cadiz, where the earthquake reached its maximum destructiveness.

83. Platania, G.

1911 Ricerche sulle oscillazioni del mare nelle coste di Sicilia. Il Nuovo Cimento, Pisa. 6th Ser. 2:349-359. Also in the Bollettino della Societa Sismologica Italiana, Modena. 15(6 & 7):223-272. (In Italian)

The origin and nature of certain rhythmic oscillations which had been frequently recorded on the Ligurian coast were studied through marigraphic analysis. The periodicities of such oscillations were also compared. It was concluded that these undulations are due to meteorological phenomena (winds, rapid variation of the atmospheric pressure, etc.). It was also observed that the periods of such oscillations and those of tsunami waves (Calabria and Messina-Calabria tsunamis) were nearly equal.

84. Platania, G.

1912 Il maremoto del 23 ottobre 1907 in Calabria e la propagazione delle onde di maremoto. Bollettino della Societa Sismologica Italiana, Modena. 16(5 & 6):166-174. (In Italian)

A description of the Calabria tsunami of 23 October 1907 is given. With marigrams recorded at Catania and Messina during the tsunamis of October 1907 and December 1908, and by assuming the coincidence of the tsunami-centers with the earthquake-epicenters, the velocities of propagation of these tsunamis were determined. It is shown that these velocities agree well with those computed by the formula $V = \sqrt{gH}$ if the sea depth along the propagation path of the tsunami is assumed to be a parabola (see No. 49).

85. de Ballore, Montessus

1912 Terremoto y maremoto del 13 de agosto de 1868. Historia

Sismica de los Andes Meridionales, Santiago de Chile. 2:77-158. (In Spanish)

In this thorough study of the Arica earthquake and tsunami of August 1868, a good deal of instrumental data regarding seismic and meteorological observations made prior to and after the phenomena as well as numerous narrations of eyewitnesses.are included. From an analysis of the times of arrival of the waves at numerous ports on the coasts of Chile and Peru, the tsunami center was approximately located and the path of propagation and velocity of the waves computed. Data concerning the arrival of the tsunami at ports along the coasts of New Zealand, Australia, Hawaii, and California are added. Finally, the computations made by Hochstetter (see Nos. 7, 9, and 11) of the velocities of propagation of this tsunami are discussed.

86. de Ballore, Montessus

1912 Terremoto y maremoto del 9 de mayo de 1877 en Chile septentrional y Peru meridional. Historia Sismica de los Andes Meridionales. Santiago de Chile. 2:162-223. (In Spanish)

From a study of the structural damage caused in southern Peru and northern Chile by the Iquique earthquake of May 1877, the positions of the quake epicenter and the isoseismal lines were determined. A geological survey of the epicentral area was made, but landslides or fissures of the ground were not found. This absence of topographical dislocations is a characteristic of the earthquakes occurring in the southern part of the Western Hemisphere. The tsunami that accompanied this earthquake was responsible for most of the damage suffered by Iquique, Arica, and other harbors situated in the epicentral area. This tsunami was recorded by tidal stations in California, New Zealand, and Japan.

87. de Ballore, Montessus

1912 Terremoto y maremoto en Concepcion y Talcahuano el 20 de febrero de 1835. Historia Sismica de los Andes Meridionales. Santiago de Chile. 4:130-173. (In Spanish)

A detailed study of the most reliable data concerning the destruction caused in Talcahuano and the islands of Santa Maria, Quiriquina, and Juan Fernandez by the Concepcion tsunami of February 1835, showed that the topographical dislocations in the epicentral region were practically negligible and the structural damage relatively small. The above conclusions contradict the statements made by Fitz Roy and Caldcleugh in their reports (See Nos. 1 and 2).

88. Sano, K., Hasegawa, K.

1915 On the wave produced by the sudden depression of a small portion of the bottom of a sea of uniform depth. Tokyo Sugaku-Buturigakkwai Kizi (Proceedings of the Tokyo Mathematico-Physical Society). 2nd Ser., 8(7):187-199.

By considering three-dimensional, irrotational motion, a mathematical computation was developed in order to determine the characteristics of the waves generated when a cylindrical area of the sea bottom subsides suddenly. The formula finally obtained for computing the elevation of the free surface of the sea at a variable distance from the center of disturbance was applied for studying the propagation of the Sanriku tsunami (Pacific coast of Northeast Japan) of 15 June 1896. The computed values agreed partially with those recorded during the phenomenon, but some substantial discrepancies were observed. These are explained by taking into consideration additional phenomena occurring near the coast where the data were recorded.

89. de Ballore, Montessus

1915 Terremoto del 16 de agosto de 1906. Historia Sismica de los Andes Meridionales, Santiago de Chile. 5:283-289. (In Spanish)

According to some foreign investigators (see Nos. 65 and 67) the severe Valparaiso earthquake of August 1906 was followed by a tsunami which was recorded on the coasts of Hawaii and Japan. In order to show that the recorded tsunami was not connected with the Valparaiso earthquake, the author points out that:

(a) The tsunami was unnoticed in the archipelago of Juan Fernandez, which is located in the assumed path of propagation, and

(b) The tidal disturbances on the Chilean coast, according to instrumental and eye observations, were practically negligible.

90. Nakamura, Saemontaro

1918 Note on tsunamis. Tokyo Sugaku-Buturigakkwai Kizi (Proceedings of the Tokyo Mathematico-Physical Society). 2nd Ser., 9(22):548-555.

It is indicated that tsunamis can be produced by submarine earthquakes, volcanic eruptions, typhoons, and meteorological disturbances. From marigraphic data recorded at the islands of Uruppo To and Ogasawara Gunto (Japan) during the North Japan tsunami of 8 September 1918, the mean oceanic depths along the propagation path of the tsunami were computed and later on compared with the values given by Milne in his study of the Iquique tsunami of 1877 (see No. 19). By using the instrumental data recorded at the North Japan tsunami an attempt was made to compute the energy of the tsunami waves and the rate of energy decay along its propagation path. Finally a list of tsunamis of meteorological origin, recorded during the period 1677-1917 in Japan, is given and their chronological distribution discussed.

91. Maso, M. Saderra

1918 Great earthquake and tidal wave in southern Mindanao. Bulletin of the Seismological Society of America. 8(4):125-126.

On 15 August 1918 a strong earthquake centering in the Celebes Sea off the southern coast of Mindanao was recorded by seismographs located at Manila. The seismic shock was followed by a tsunami which swept the coast of Mindanao causing considerable destruction. The devastated region is inhabited by wild tribes, which will make it difficult, if not impossible, to obtain information regarding the extent of the damage and the number of casualties.

92. Reid, H. F. and Taber, S.

1919 The Porto Rico earthquake of 1918. Report of the Earthquake Investigation Commission, House of Representatives, Document No. 269. Washington, D. C., pp. 25-31.

The Puerto Rico earthquake of 11 October 1918 was accompanied by a destructive tsunami which reached heights of 4.5 meters above the mean sea level at ports located along the northwest coast of Puerto Rico. It was recorded by tide gages on Haiti, the Dominican Republic, and Atlantic Coast of U. S.A. The earthquake had a submarine focus, and its epicenter was apparently located in the northeastern part of Mona Passage. The breakage of several telegraphic cables lying on the epicentral area suggested that large dislocations or landslides took place in the bed of the sea at the time of the seismic shock.

93. Linneman, C.

1919 Resena sobre el terremoto de Copiapo. Boletin Minero de la Sociedad Nacional de Mineria, Chile, pp. 412-420. (In Spanish)

The Copiapo tsunami of 4 December 1918 caused damage in the port of Caldera where it reached a height of about 5 meters above the level of normal tides. After the earthquake which preceded the tsunami, a few fissures parallel to the coast were observed on the beach of Caldera.

94. Reid, H. F. and Taber, S.

1919 The Porto Rico earthquake of October-November 1918. Bulletin of the Seismological Society of America. 9(4):110-114.

A summary of No. 92.

95. Davison, C.

1921 A manual of seismology. Cambridge University Press. Chapter VI.

Based on Mallet's catalog of earthquakes (see No. 4) and data collected during the largest observed tsunamis, a general study of tsunami generation and propagation was made. It was concluded that the largest tsunamis have been caused by abrupt formations of submarine fault-scarps. The earthquakes which produced these faults had their epicenters either wholly or partially under the sea. The heights reached by the water during major tsunamis are given, and a study of the propagation of these tsunamis is made. Finally the nature of the oscillations produced in bays by the progressive tsunami waves is analyzed.

96.

1923 Earthquake wave in Hawaii. Monthly Bulletin of the Hawaiian Volcano Observatory, Honolulu. 11(2):11.

On 3 February 1923 a tsunami was recorded at the port of Hilo, where the waves reached heights of 20 feet. It is believed that this tsunami, which was also observed in Honolulu and other ports on the Hawaiian Islands, was connected with the earthquake which took place a few hours earlier near the Aleutians.

97. Selga, M.

1923 The Zamboanga mareogram of the Coquimbo earthquake. Proceedings of the Pan Pacific Science Congress, Sidney Meeting of August-September 1923. 1:587-590.

The Atacama earthquake of 10 November 1922 was of submarine type, therefore giving rise to a tsunami which swept the coast of Central Chile, causing considerable destruction. According to marigrams recorded at Zamboanga (Mindanao) the waves, which had an average length of 1,130 kilometers, were propagated towards Zamboanga with a mean velocity of 410 miles per hour. However, computations made by using Japanese marigraphic data showed that the tsunami was propagated toward Japan with an average speed of 208 meters per second, and the mean length of the waves was about 372 kilometers. The remarkable difference between computations are explained by considering the topographic conditions of the observing stations and the marked differences between the two paths of propagation.

98. Belot, E.

1923 Sur une forme de volcanisme latent en relation avec les tremblements de terre et les raz de maree. Comptes Rendus de l'Academie des Sciences, Paris. 177:700-703. (In French)

Vulcanism has always been defined as the phenomenon caused by the subterranean action of gas and vapor whose pressures are capable of bringing melted materials from the earth's interior up to the ground level. In this paper the author suggests also the inclusion under vulcanism of the cases where the pressures of the gas are unable to lift the melted substances up to the ground level and where the internal temperatures are lower than the melting point of rocks. This vulcanism would be found in a new type of "internal volcano" without craters, which would be located mainly on unstable coasts. It is believed that the eruptions of these internal volcanoes were the main cause of some Japanese earthquakes which were accompanied by tsunamis. According to this theory, the eruptions of the internal volcanoes would produce big fissures in the ocean bed (openings of craters). The sea water would rush into these craters producing a sudden depression of the sea surface which would cause a tsunami. The formation of these fissures also would produce seismic shocks of great violence. The fact that in most of the Japanese tsunamis the first motion of the water was a downfall of the sea level (negative wave) would confirm this theory. On the other hand, it has been observed that the earthquakes preceding tsunamis are of surface-foci type, the depths of their hypocenters being between 10 and 15 kilometers. At these depths internal temperatures of 300 to 450°C. are lower than the melting point of rocks. Based on this theory the author carried out a model experiment on the mechanism of tsunami generation, concluding that the theoretical and experimental values agreed remarkably.

99. Suda, K. and Seki, K.

1923 On a few tsunami waves which occurred recently in the Pacific. Umi to Sora (Sky and Water). 3:95-98, 111-114. (In Japanese)

The velocities of propagation of the Atacama tsunami of 1922 and of the Aleutain tsunami of 1923 (see Nos. 96 and 97) were computed by using marigrams recorded at Japanese stations. From these values the mean depths of the ocean were computed by the formula $H = V^2/g$. The discrepancies between the computed values and the real depths, obtained by soundings, are explained by taking into consideration the complex topography of the ocean bed. The rates of damping of tsunami waves are discussed and an attempt is made to use these values as a means of determining the coefficient of viscosity of the sea water. In addition, the modes of oscillation of tsunamis in bays are studied, it being concluded that the second and third harmonics of the fundamental period are highly predominant.

100. Finch, R. H.

1924 On the prediction of tidal waves. Monthly Weather Review. 52(3):147-148.

Tsunamis are due to topographical changes occurring on the sea bottom and their velocities of propagation depend on the mean depth of the seas traversed. The destruction they cause on shores is closely related to their heights and periods, factors depending mainly, as it had been observed in Japan, on the coastal topography. Experience gained during the Aleutian tsunami of February 1923 indicates that it is possible to predict accurately the approach of tsunamis, because the seismic waves of the earthquake associated with the tsunami are registered by seismographs several hours prior to the arrival of the sea waves.

101. Tyosi Meteorological Observatory

1924 Note on the waves and tides on the day of the great earthquake. Journal of the Meteorological Society of Japan. 43:88-91. (In Japanese)

Forty-five minutes after the great Kwanto (southeast Japan) earthquake of 1 September 1923, the tide gage at Tyosi Meteorological Observatory recorded the arrival of a few waves with an average period of 10 minutes, followed by a group of regular waves reaching a maximum amplitude of 0.82 meter. After these waves the oscillations became somewhat irregular. It is pointed out that since January 1923 the sea level had been gradually rising and that throughout the tsunami the mean level sank slowly until reaching the level of normal tides.

102. Imperial Naval Hydrographical Dept.

1924 Report of the Hydrographic survey of Sagami Nada after the great earthquake of September 1, 1923. Imperial Naval Hydrographical Department, Tokyo. (In Japanese)

The Kwanto earthquake of 1923 apparently originated on the ocean bed of Sagami Nada about 80 kilometers southwest of Tokyo. A comparison of the values obtained by sounding surveys carried out in 1912 and immediately after the phenomenon shows that:

(a) The sea bottom appeared generally depressed in the southwest part of Sagami Nada and upheaved in the northeast part,

(b) The depression took place in deep water (over 1,300 meters depth) and covered an area of about 32 square nautical miles,

(c) The maximum vertical depression recorded was about 180 meters and

(d) In the northeast part of Sagami Nada, upheavals of more than 100 meters were recorded in a wide area.

These remarkable topographical changes seem to be responsible for the tsunami that accompanied this earthquake.

103. Imamura, A.

1924 Preliminary notes on the great earthquake of southeast Japan on September 1, 1923. Seismological Notes of the Imperial Earthquake Investigation Committee, Tokyo. 6:1-22.

Much instrumental data concerning the Kwanto earthquake and tsunami of September 1923 are given. In regard to topographical changes accompanying these phenomena, it is indicated that:

(a) Triangulation and level surveys carried out by the Land Survey Department (Japan) soon after the earthquake showed that important landslides had occurred on the peninsulas of Miura, Idu, and Boso and on the mountainous districts of southwest Sagami, and

(b) Sounding surveys made by the Imperial Naval Hydrographical Department (see No. 102) showed that important dislocations of the sea bottom had taken place in Sagami Nada.

The heights reached by the tsunami at several ports are tabulated and the effects of coastal configuration and sea bed slope upon tsunami propagation are studied. Two appendices accompany this paper. The first one includes a catalog of destructive earthquakes recorded at Japan since 1596 with a description of the Japanese seismic zones; the second gives a further account of the topographical changes accompanying the earthquakes.

104. Suda, K.

1924 On the great earthquake of September 1, 1923. Memoirs of the Imperial Marine Observatory, Kobe. 1:138-239.

Gives detailed account, including abundant non-instrumental data obtained by questionnarie from eyewitnesses, of the violent Kwanto earthquake and tsunami in September 1923. After the earthquake noticeable vertical displacements of the land were observed. In order to learn about the mechanism of generation of the earthquake and tsunami, an interesting geological study of the epicentral area was carried out.

105. Ikeda, T.

1925 Tsunamis or seismic tidal waves. Shinsai Yobo Chosaki Hokoku (Reports of the Imperial Earthquake Investigation Committee). 100-B: 97-112. (In Japanese)

The Kwanto tsunami of 1923, even though it propagated to great distances, caused damage only to ports located in the epicentral area (Sagami Nada), reaching maximum destructiveness on the V-shaped bays of Atami Hakuchi, Ajiro Ko, and Ainohama. It was observed that although the waves were relatively small at the entrances of these bays, they reached destructive heights at their inner ends, suggesting that the destruction caused by tsunamis in bays depends mainly upon the topography of the coast.

A study of the directions of propagation of the tsunami and of the reflections of the waves in these bays indicated that the tsunami was generated on the upheaved zone of Sagami Nada (see No. 102) and that the enormous depression observed on the southwest part of this bay played only a small part in the production of the tsunami. This hypothesis is confirmed by the fact that the preliminary motion of the water on the coast was an elevation of the sea level (positive wave), which, according to data recorded in previous tsunamis, is quite unusual.

106. Terada, T. and Yamaguti, S.

1925 On the propagation of the tsunami that started from Sagami Nada. Shinsai Yobo Chosaki Hokoku (Reports of the Imperial Earthquake Investigation Committee), Tokyo. 100-B:113-120. (In Japanese)

By using marigrams recorded during the Kwanto tsunami of 1923 at several tidal stations located along the Pacific coast of Japan and on the coasts of the Japan Sea, the periods of the most important oscillations in the bays were computed and the propagation of the tsunami was discussed. It was concluded that:

(a) Oscillations with periods of about one hour predominated in all the bays studied, and

(b) The tsunami was generated by vertical displacements occurring in the floor of Sagami Nada (see No. 102).

107. Jaggar, T. A.

1925 Tidal waves. The Volcano Letter, Hawaii. No. 50.

Tsunamis are caused either by suboceanic earthquakes or by meteorological phenomena such as typhoons. A study of the geographical distribution of major tsunamis showed that the Atlantic coasts are practically free of them, but along the Pacific shores of southern Latin America and Japan they are notoriously frequent. Information is summarized regarding some major tsunamis originating on the coasts of Chile and Peru, which were recorded at the Hawaiian Islands.

108. Jaggar, T. A.

1926 Forewarning of tidal waves in Hawaii. The Volcano Letter, Hawaii. No. 57.

On January 24, 1926 a tsunami following a strong earthquake of unknown origin was registered at the Hawaiian Islands, which is the best observation station for recording tsunamis originating either on the Pacific coast of the Americas or Japan. To corroborate the importance of Hawaii as a place for tsunami observation, a list of the tsunamis recorded there during the last years is given.

109. Wilson, R. M.

1926 The tidal wave in Palmerston Island. The Volcano Letter, Hawaii. No. 93.

On 12 May 1926 a tsunami swept the coasts of Palmerston Island, located about 300 miles northwest of Raratonga, destroying all the buildings there.

110. Imamura, A.

1926 The great earthquake of southeast Japan on September 1, 1923. Scientific Japan, Third Pan-Pacific Science Congress, Tokyo. pp. 141-176.

This paper is the same as that listed under No. 103 of this bibliography.

111. Wilson, R. M.

1928 Seismic sea waves at Hilo, 1927. Monthly Bulletin of the Hawaiian Volcano Observatory, Honolulu. 16(3):21-25.

During the year 1927 the tide gage at Hilo recorded the arrival of the tsunamis which accompanied the earthquake of California (4 November 1927) and Kamchatka regions (28 December 1927). Marigraphic data concerning the times of arrival of both tsunamis and the characteristics of the waves at Hilo are given. The velocities of propagation of both tsunamis, computed from the marigraphic data were found to be nearly equal (approximately 200 miles per second). Finally some information is given concerning tsunamis which had been recorded in previous years at Hilo and other ports in the Hawaiian Islands.

112. Imamura, A.

1928 On the destructive Tango earthquake of March 7, 1927. Bulletin of the Earthquake Research Institute, Tokyo Imperial University. 4:179-202. (In Japanese with English summary)

A few hours after the Tango (Japan) earthquake of 27 March 1927, a small tsunami, quite harmless, was recorded in several ports on the

Japan Sea. Permanent upheavals of about 0.80 meter occurred along the coast of the Japan Sea and temporary elevations of the coast seemed also to have taken place a short time before the great seismic shock.

113. Wilson, R. M.

1928 The seismic sea wave at Hilo. Monthly Bulletin of the Hawaiian Volcano Observatory, Honolulu. 16(6): 41-42.

On 17 June 1928 the tide gage at Hilo recorded the arrival of the tsunami which accompanied the Mexican earthquake of 16 June. The earthquake centered in the Acapulco Deep (Pacific Ocean) about 125 miles off the Mexican coast. The tsunami caused considerable damage in the epicentral area, being especially severe on the ports of Chacahua and Puerta Angel. Instrumental data concerning the times of arrival and characteristics of the waves at Hilo are given. The velocity of propagation of the waves calculated from the marigraphic data was approximately 203 meters per second.

114. Jaggar, T. A.

1929 Seismic sea wave of March 6, 1929. The Volcano Letter, Hawaii. No. 220.

On 6 March 1929 a strong submarine earthquake centering on the northern slope of the Aleutian Trench about 100 miles south of Amukta Island was followed by a tsunami which was recorded by the marigraph at Hilo Bay, Hawaii. Even though the seismic shock was as strong as that occurring in the same area in February 1923 (see No. 96), its tsunami was smaller, suggesting that the magnitude of tsunamis can be strongly affected by the winds and tides prevailing on the traversed seas. The marigraphic data also showed that the tsunami of 1929 apparently traveled faster than that of 1923.

115. Willis, B.

1929 Earthquake conditions in Chile. Carnegie Institution of Washington, Publication No. 382.

A brief description of 22 severe earthquakes which had occurred on the northern coast of Chile is given. Five of these earthquakes were accompanied by tsunamis. Abundant non-instrumental data regarding the Atacama tsunami of 10 November 1922 are added. For tracing active faults a careful examination of the epicentral area of the Atacama earthquake was made, but important fissures or landslides were not found. From a very detailed study of the geological features of this area, it is concluded that the earthquakes observed in northern Chile were mainly of submarine focus type.

116.

1929 Submarine landslides. Science, Supplement (Science News). Vol. 170, p. X.

The Newfoundland earthquake of 18 November 1929 centered just off the edge of the continental shelf, where the ocean bottom has a steep slope and the seismic shaking therefore can easily produce important landslides. That such landslides took place during this earthquake is shown by the tsunami and breakage of transoceanic cables which accompanied the seismic shock.

117. Gregory, J. W.

1929. The earthquake south of Newfoundland and submarine canyons. Nature, London. 124:945-946.

The Newfoundland earthquake of 17 and 18 November 1929 caused a tsunami which inundated the coastal area of Burin Peninsula and in places swept inland to the height of 100 feet. The breakage of 11 transoceanic cables lying on the epicentral area indicated that the earthquake was probably due to a renewed subsidence of the submarine southern continuation of Cabot Strait. The geological features of the epicentral area are studied, and it is pointed out that a similar geological configuration is found at several places along the eastern coast of Canada and U. S. A. and that probably a further study of the seismic shock will reveal important facts concerning the geological formation of these regions.

118. Jaggar, T. A.

1929 A big Atlantic earthquake. The Volcano Letter, Hawaii. No. 261.

The Newfoundland earthquake of November 1929 centered about 180 miles south of the Newfoundland coast, off the edge of the continental shelf, and apparently caused important topographical changes on the sea bottom. The fact that the sea bottom in the epicentral area is fairly steep and that breakage of several transoceanic cables was observed immediately after the phenomenon would tend to confirm the existence of such displacements. The tsunami was especially severe at Placentia Bay where it caused heavy structural damage. Data regarding casualties and details of the nature of the ruptures of the cables are added.

119. Dominion Observatory, Ottawa

1930 Preliminary notes on the Grand Banks earthquake of November 18, 1929. Earthquake Notes, Eastern Section of the the Seismological Society of America. 1(3):3.

During the Newfoundland earthquake of November 1929, a group of waves propagating northward from the epicentral area caused considerable damage at Placentia Bay (located about 300 miles from the epicenter) even though Sable Island, lying less than 100 miles from the tsunami center, escaped undamaged. The southward propagation of the tsunami was rather negligible, since the tide gage on the Atlantic coast of Canada registered only slight tidal perturbations.

120. U. S. Coast and Geodetic Survey

1930 Preliminary information on the Grand Banks Earthquake. Earthquake Notes, Eastern Section of the Seismological Society of America. 1(3):4-5.

Marigraphic data registered at stations in Maryland and South Carolina during the Newfoundland tsunami of November 1929 showed that the waves were propagated towards these stations with velocities between 240 and 286 miles per hour. A severe storm which was raging along the New England coast made it impossible to appreciate the magnitude of the tidal disturbances caused by the tsunami in the northeast coast of U.S.A.

121. Jaggar, T. A.

1930 Ocean waves from submarine earthquake. The Volcano Letter, Hawaii. No. 274.

Most of the earthquakes originating off the Alaskan coast or in the Aleutian archipelago affect the topography of the sea bottom, therefore causing tsunamis which are generally propagated southward and registered at the Hawaiian Islands. A study of the seismic history of Hawaii shows that 11 tsunamis of perceptible magnitude have been recorded there and that their velocities of propagation fluctuated between 284 and 481 statute miles per hour. Finally, information concerning the Aleutian tsunamis of February 1923 and March 1929 is added and the destruction they cause in Hawaiian ports is compared.

122. Hodgson, E. A. and Doxsee W. W.

1930. The Grand Banks earthquake, November 18, 1929. Eastern Section of the Seismological Society of America, Proceedings of the 1930 meeting, Washington, D. C., May 1930, pp. 72-81.

The Newfoundland earthquake of 18 November 1929 was apparently generated by two seismic faults which extended for an approximate length of 375 miles parallel to the axis of Cabot Strait. The earthquake was accompanied by a tsunami, caused apparently by dislocations of the sea bed in the epicentral area. Rupture of several transoceanic cables lying in the affected area confirmed the existence of such topographical dislocations. However, the sounding surveys completed to date show only small vertical displacements of the sea bed (less than 8 meters).

123. Keith, A.

1930 The Grand Banks earthquake. Eastern Section of The Seismological Society of America, Supplement to the Proceedings of the 1930 Meeting, Washington D. C., pp. 1-5.

The Newfoundland earthquake of November 1929 was felt at Washington D. C. and Baltimore, Maryland at approximately 2,000 kilometers from the earthquake epicenter. The tsunami which accompanied this earthquake rose to approximately 17 meters above the level of normal tides on the southern coast of Burin Peninsula, where it destroyed several fishermen's villages. From a study of the breaking of several telegraphic cables, the position of the tsunami center was established and found to coincide with the location of the earthquake epicenter.

124. McIntosh, D. S.

1930 The Acadian-Newfoundland earthquake. Proceedings and Transactions of the Nova Scotian Institute of Science, Halifax. Pt. 4, 17:213-222.

The Newfoundland earthquake of November 1929 was apparently caused by vertical displacements of the ocean bed which buried several telegraphic cables crossing the epicentral area. By considering that the epicentral area is in a line with the old submerged channel of the St. Lawrence River, it is indicated that a setting of the sediments accumulated seaward from the river mouth was probably the primary cause of the earthquake. The seismic shock was followed by a tsunami which caused great destruction along the coasts of Burin Peninsula. Finally, it is pointed out that tsunamis are a usual accompaniment of submarine earthquakes and that the dimensions of the waves depend upon the intensity of the seismic shocks.

125. Johnston, J. H. L.

1930 The Acadian-Newfoundland earthquake of November 18, 1929. Proceedings and Transactions of the Nova Scotian Institute of Science, Halifax, Pt. 4, 17:223-237.

Marigrams recorded at Halifax during the Newfoundland tsunami of November 1929 showed that the waves propagated towards that port with a velocity of approximately 165 kilometers per hour and that the periods of the fundamental components of the sea level oscillations (inside the bay), fluctuated between 5 and 150 minutes. Non-instrumental data regarding the times of arrival of the tsunami at different ports along the coasts of Newfoundland were used to analyze the propagation of the waves within the epicentral region.

126. Jaggar, T. A.

1931 Hawaiian damage from tidal waves. The Volcano Letter, Hawaii. No. 321.

A list of the tsunamis recorded at Hawaii during the last century is given. Among the largest tsunamis listed are those of southern Chile (November 1837), Arica (August 1868), Kau (April 1868), and Iquique (May 1877). Information concerning the structural damage caused at Hawaiian ports by such tsunamis is added.

127.

1931 The Newfoundland earthquake of November 18, 1929. Nature, London. 127:836.

Summary and comparative study of the results found by Messrs. Gregory, Hodgson, Doxsee, and Keith (see Nos. 117,122,and 123) in their studies of the Newfoundland earthquake and tsunami of November 1929.

128. Jones, A. E.

1931 Earthquake and sea wave of October 3, 1931. The Volcano Letter, Hawaii. No. 361.

On 3 October 1931 an earthquake centering on the vicinity of Rennell Island (southeast of New Guinea) was accompanied by a tsunami which caused great damage in the central and eastern Solomons, being especially severe at San Christoval Island, where it destroyed several native villages. The tsunami propagated toward Hawaii where it caused small perturbations of the sea level which were perceptible only to the marigraphs, even though the phenomenon lasted for about 48 hours.

129. Heck, N. H. and Bodle, R. R.

1931 The Grand Banks earthquake of November 18, 1929. United States Earthquakes 1929, U. S. Coast and Geodetic Survey, Serial No. 511, Washington, D. C., pp. 28-29.

The Newfoundland earthquake of November 1929 was felt in the New England States and southern Canada. The fact that this shock was accompanied by a large tsunami and breaks of numerous transoceanic cables indicates that important vertical displacements of the sea bed took place during the phenomenon. The nature and magnitude of such displacements are unknown, however, due to the lack of adequate data concerning the topography of the submarine epicentral area before the seismic shock. Some information regarding the frequency and nature of the rupture of cables lying on this area is added.

130. Mallandra, A.

1931 La raz de maree ou tsunamis dans le Golfe de Naples. Union Geodesique et Geophysique Internationale, Annales de la Commission pour l'Etude des Raz de Maree, Paris. 1:48-53. (In French)

Tsunamis are due mainly to seismic disturbances in the sea bed and are rarely caused by volcanic eruptions. However, a study of old records has shown that most of the eruptions of Vesuvius have caused tidal disturbances of some magnitude. The periods of activity observed in Vesuvius since 79 A.D. are listed and the cases where the eruptions are accompanied by tsunamis are indicated.

131. Davison, C.

1931 The Japanese earthquake of 1923. London. Chapter XII.

A description is given of the damage caused in ports along the coast of Sagami Nada by the Kwanto earthquake and tsunami of September 1923. The maximum height reached by the tsunami in the vicinity of the coast was 36 feet according to Prof. Suda and 39 feet according to Prof. Imamura. The tsunami was caused by displacements of the floor of Sagami Nada. From sounding surveys carried out in 1912 and after the tsunami (see No. 102), it was found that the maximum depression of the sea bed was 1,312 feet and the largest upheaval 755 feet. In spite of those enormous dislocations the tsunami was comparatively small, which can be explained by considering that part of the displacement shown by the soundings took place gradually during the 10-year interval between the first sounding survey and the occurrence of the tsunami.

132. Patton, R. S. and Marmer, H. A.

1932 The waves of the sea. Bulletin of the National Research Council, Physics of the Earth (Oceanography). pp. 222-225.

A brief report of basic knowledge of tsunamis is given. It is indicated that despite its slight compressibility, sea water responds as an elastic body to the short-period oscillations of submarine earthquakes. Owing to this property of the sea water, seismic waves would be partially transmitted to the water in the form of longitudinal vibrations which would travel to the sea surface generating small tsunamis. Occurrence of larger tsunamis would require dislocations of the sea bed.

133. Davison, C.

1933 The recent Japanese earthquake. Nature, London. 131:351-352.

The epicenter of the great Sanriku earthquake occurring off the northeast coast of Japan on 3 March 1933 lay near the western slope of the Tuscarora Deep (trench in the Pacific Ocean) about 140 miles from the northeast coast of Japan. The depth of water in this region is about 4.5 miles. The tsunami which accompanied this earthquake was responsible for most of the damage caused on the epicentral area. This tsunami was recorded at Honolulu and San Francisco Bay, the latter about 4,800 miles from the earthquake epicenter.

134. Jaggar, T. A.

1933 Tsunami or earthquake tidal wave of March 2, 1933. The Volcano Letter, Hawaii. No. 397.

The Sanriku earthquake of March 1933 centered on the western slope of the Tuscarora Deep, about 125 miles east of Matsushima, Japan and was accompanied by a tsunami which caused some minor damage at Hawaiian ports. The seismographs at Hawaii registered the seismic waves of the earthquake, thus permitting the Hawaiian Volcano Observatory to warn the ports of the approach of the tsunami, which arrived several hours later.

135. Imamura, A.

1933 On the tsunami of N. E. Japan on March 2, 1933. Proceedings of the Imperial Academy of Japan, Tokyo. 9(4):174-177.

About 25 to 40 minutes after the Sanriku earthquake of March 1933, a tsunami swept the coasts of northeast Japan, causing enormous destruction. Apparently this tsunami originated in the same way as that which occurred in this area in 1896, namely, in the Tuscarora Deep which is a notorious "breeding ground" for tsunamis. The exact location of the tsunami center can be probably obtained by studying the vertical components of the submarine crustal deformations. This study is now being made by using sounding surveys made soon after the phenomenon. It is finally pointed out that every destructive tsunami originating on the Pacific side of Japan has almost without exception followed a short time after a large inland earthquake or volcanic eruption.

136. Ishimoto, M.

1933 Preliminary notes on the tsunami of March 2, 1933 (G.M.T.) and an outline of the investigations now being made concerning it at the Earthquake Research Institute. National Research Council of Japan, Japanese Journal of Astronomy and Geophysics. 11(1):1-10.

Immediately after the Sanriku tsunami of March 1933, the Earthquake Research Institute sent several investigators to the scene of the disaster to collect data regarding tsunami phenomena. The subjects under study are enumerated and details of progress so far attained are given. Note: The reports containing the final results of these studies were published later in a special supplement of the Bulletin of the Earthquake Research Institute and are summarized under No. 142 to No. 153, inclusive, of this bibliography.

137. Matuzawa, T., Kanbara, K., and T. Minakami

1933 Horizontal movement of water in the tsunami of March 3, 1933. National Research Council of Japan, Japanese Journal of Astronomy and Geophysics. 11(1):11-16.

The main elements of tsunamis to be considered in a study of tsunami destructiveness are height of the waves and velocity of the flow. It is shown that in some special cases the relation between harbor topography and tsunami heights can be expressed mathematically. In regard to flow velocity, an average value of 8 meters per second was determined by using non-instrumental data recorded mainly during the Sanriku tsunami of 1933.

138. Imamura, A. and Kawase, Z.

1933 The Sanriku tsunami of 1933. National Research Council of Japan, Japanese Journal of Astronomy and Geophysics. 11(1):17-35.

Statistics on casualties and structural damage caused by the Sanriku earthquake and tsunami of March 1933 on 75 villages along the northeast coast of Japan are given and descriptions of some phenomena (luminosities, sounds, etc.) accompanying the disaster are added. By studying data recorded during the Sanriku tsunamis of 1896 and 1933, it is concluded that the coastal configuration is chiefly responsible for the great damage caused in this area by tsunamis. In fact, the northeast coast of Japan presents numerous V- and U-shaped bays opening towards the Tuscarora Deep, on the slope of which gigantic earthquakes have frequently taken place. Finally, some suggestions concerning mitigation of tsunami disasters are included.

139. Kishinouye, F.

1933 Some notes on the Sanriku tsunami of 1933. Disin (Earthquake). 5:760-763. (In Japanese)

The remarkable heights reached by the water at Misawa (Hachinohe) and Erimo Saki (Hokkaido) during the Sanriku tsunami of March 1933 are explained to be due to the convergence of the waves. The enormous quantities of sand thrown upon shore by the tsunami showed the great turbulence of the waves on the sea bed near the coast.

140.

1933 Notes on the prevention of damage from tsunamis. Especial publication of the Imperial Earthquake Investigation Council, Tokyo. pp. 1-10.

The efficiency of structures for harbor protection in resisting tsunamis was studied by using data recorded at several places along the northeast coast of Japan during the Sanriku tsunamis of 1896 and 1933. After a careful study of the influence of coastal configuration and sea bottom topography upon the destructive power of tsunamis, the efficiency of several types of breakwaters was analyzed. A list of protective measures for mitigating the damage and destruction caused by large tsunamis is added. Most of the safety precautions were prepared for use in ports and villages along the coast of the Sanriku district and would require modification to be applied to other places.

141. Bobillier, C.

1933 Historia de los maremotos sucedidos en Chile desde el ano 1562 el ano 1932. Boletin del Servicio Sismologico de la Universidad de Chile, Santiago. 23:34-41. (In Spanish)

A description of 12 destructive tsunamis recorded along the coasts of Chile during the period 1562-1932 is given, including mainly non-instrumental data regarding casualties, structural damage, and height reached by the water on the coast. These tsunamis were preceded by strong earthquakes. Tidal disturbances that apparently were not related to seismic shocks have been frequently recorded on the southern coast of Chile. These disturbances would be caused by oceanic storms occurring off the coast of the Magellan Strait. Oceanic currents would be responsible for the propagation of these disturbances along the Chilean coasts.

142. Ishimoto, M. and Hagiwara, T.

1934 The tsunami considered as a phenomenon of sea water overflowing the land. Bulletin of the Earthquake Research Institute, Tokyo Imperial University, Supplementary. 1:17-23.

A very complete description of the structural damage provoked at Kamaishi Wan (northeast Japan) by the Sanriku tsunami of March 1933 is given. Diagrams showing the damage distribution and height reached by the water at the bay are added. Finally, an attempt is made to determine the influence of the coastal topography upon the velocity of propagation of tsunami waves.

143. Terada, T.

1934 Luminous phenomena accompanying destructive sea waves. Bulletin of the Earthquake Research Institute,,Tokyo Imperial University, Supplementary. 1:25-34. A summary of this report was published previously in the Proceedings of the Imperial Academy of Japan, 9:367-369. November 1933.

During the Sanriku tsunami of 1933 some luminous phenomena were observed, among them a strong flash of light which seemed to have been emitted from the sea surface near the mouth of Kamaishi Wan. After analyzing the probable cause of this phenomenon, it is concluded that it was caused by luminous plankton (mainly Noctiluca miliaris) which were excited to a continuous and simultaneous luminosity either by the turbulence engendered by the tsunami or by some electrical phenomenon caused by the waves. Since the luminosity produced by these organisms is very small, a clearly perceptible light would require the presence of a great number of them over a large area, suggesting that the tsunami disturbed an area of several square kilometers to a considerable depth.

144. Yamaguti, S.

1934 Abnormally high waves or tsunamis on the coast of Sanriku, on March 3, 1933. Bulletin of the Earthquake Research Institute, Tokyo Imperial University, Supplementary. 1:36-52.

A study of the topographical features and modes of oscillation of 45 bays along the coast of the Sanriku districts and of the heights reached in them by previous tsunamis shows that:

(a) Most of the bays studied presented nearly equal periods of oscillation,

(b) The higher waves (over 10 meters) generally occurred in deeper bays and comparatively low waves (heights less than 5 meters) were frequent in shallow bays,

(c) The height of the waves is inversely proportional to the period of the bays,

(d) The great damage caused by tsunamis on these coasts seemed to be due, in part, to the greater depth of the sea along the shore, and

(e) In general, higher waves were observed in V-shaped bays.

145. Matuo, H.

1934 Estimation of energy of tsunami and protection of coasts. Bulletin of the Earthquake Research Institute, Tokyo Imperial University, Supplementary. 1:55-64.

An attempt to compute the forces which act upon structures during tsunamis is made by using instrumental data recorded during the Sanriku tsunami of March 1933. The change of height of the waves in bays opening obliquely to the direction of propagation of the tsunami was computed and the effect of the slope of the sea bottom upon tsunami heights was studied. The structural characteristics of several sea walls in the affected area and the damage caused to them by the tsunami were carefully studied in order to compute the pressures exerted by the waves on these structures. Finally, general descriptions of practical methods of coast protection are enumerated and their efficiency against tsunamis are discussed.

146. Matuo, H.

1934 Experimental investigation on prevention of damage of tsunamis. Bulletin of the Earthquake Research Institute, Tokyo Imperial University, Supplementary, 1:65-75.

A model experiment was carried out to develop a method for predicting damage caused by tsunamis. Using a long solitary wave, to simulate the tsunami, the following tests were made:

(a) Propagation of the wave in a smooth-sloped channel. It was established that: 1) the wave heights are inversely proportional to the water depth 2) the steeper the slope, the less liable is the wave to break,

(b) Effect of the wave against breakwaters. The efficiency of breakwaters (lying parallel to the coast) against tsunamis is inversely proportional to their distance from the coast, and

(c) Effect of the wheeling of the wave. The change occurring in tsunamis coming into bays opening obliquely to their direction of propagation was tested and the results compared with values computed by applying the formula of Prof. Hiroi.

147. Musye, K.

1934 On the luminous phenomena that accompanied the great Sanriku tsunami of 1933. Bulletin of the Earthquake Institute, Tokyo Imperial University, Supplementary. 1:87-110.

In order to learn about the nature and cause of luminous phenomena which usually accompany Japanese tsunamis, numerous descriptions of eyewitnesses regarding the luminescence seen on the sea surface during the Sanriku tsunami of 1933 were collected. An analysis of these data showed that these phenomena were produced by luminescent plankton organisms, mainly Noctilucas, and some luminescent jellyfish such as Pelagia and Ctenophora. In order to ascribe such strong luminescence to phosphorescent plankton, it was necessary to admit that a large number of such microorganisms were present in the coastal water of the affected shores at the time of the tsunami, which is unusual during the month of March.

148. Miyabe, N.

1934 An investigation of the Sanriku tsunami based on marigram data. Bulletin of the Earthquake Research Institute, Tokyo Imperial University, Supplementary. 1:112-125.

Based on marigrams recorded in Japan, Honolulu, and the west coast of the Americas, the source and time of commencement of the Sanriku tsunami of March 1933 were determined. By considering first only the marigrams recorded at Japanese stations and assuming the tsunami propagated with the velocity $V = \sqrt{gH}$, the geographical position of the tsunami center was determined. It is shown from the above results that the tsunami could not be propagated from a point source unless it had started some time before the occurrence of the earthquake. The travel times to stations located in the Americas were also calculated by assuming that the average depth of the Pacific Ocean is 4,000 meters.

149 Otuka, Y.

1934 Tsunami damages on March 3, 1933 and the topography of Sanriku coast, Japan. Bulletin of the Earthquake Research Institute, Tokyo Imperial University, Supplementary. 1:127-151. (In Japanese with English summary)

Based on data recorded during the Sanriku tsunami of 1933, the effect of coastal topography upon destructive power of tsunamis was discussed, it being concluded that tsunamis reach maximum heights on shores facing the open sea. From a geological study of the area affected by this tsunami, it is concluded that the coast of Sanriku was submerged a few hundred meters during post-Pleistocene time. The gradual upheaval gave this region special topographical features which are partially responsible for the great destruction caused by tsunamis on these shores. In fact, these coasts are notoriously flat and great oceanic depths are found very near the shore. These factors explain why tsunamis can flood this area to a considerable height. In addition, the existence of numerous U- and V-shaped bays increases the vulnerability of the area.

150. Takahasi, R.

1934 A model experiment on the mechanism of seismic sea wave generation. Bulletin of the Earthquake Research Institute, Tokyo Imperial University, Supplementary. 1:152-178.

By assuming that tsunamis are produced by dislocations of the sea bottom, the mechanism of their generation was studied through a model experiment. A wooden tank was used, having a circular mobile piston fitted in its center to simulate the upheaval (or downfall) of the sea bed. By using different waters depths and piston velocities, a total of 45 tests was carried out. It was found that:

(a) The velocity of propagation of the generated waves in the immediate neighborhood of the center of disturbance is larger than that given by the formula $V = \sqrt{gH}$, but approaches asymptotically to V with increasing distance from the center,

(b) The height of the progressive circular wave apparently decreases as $d^{-0.6}$ (d being the distance from the center of disturbance to the point where the height is measured), within the region observed, and

(c) The elevation of the water surface depends mainly on the dropping velocity of the sea bottom dislocation.

151. Nasu, N.

1934 Heights of tsunamis and damage to structures. Bulletin of the Earthquake Research Institute, Tokyo Imperial University, Supplementary. 1:218-226.

In order to determine the geographical features of the areas inundated by the Sanriku tsunami of 1933, triangulation and leveling surveys were carried out on 14 bays along the coast of the Sanriku district. The topographical maps obtained and a separate description of the structural damage caused by the tsunami in each of these localities are added. The relation between the heights reached by the water during the tsunami and the geographical features of the affected area is discussed and the minimum height of water able to produce structural damage is studied.

152. Suyehiro, Y.

1934 Some observations on the unusual behavior of fishes prior to an earthquake. Bulletin of the Earthquake Research Institute, Tokyo Imperial University, Supplementary. 1:228-231.

Several investigators have proved the existence of an instinctive reaction of fishes to earthquakes. This curious fact also was observed during the Sanriku tsunami of 1933. Sardines caught a few hours before the occurrence of the tsunami showed that their stomachs were swelled by their contents to an abnormal degree. In addition, the fact that these fishes had fed mainly on bottom-adherent diatoms indicated that such diatoms had appeared in large quantities in the upper layer of the sea, possibly due to disturbances taking place in the sea bottom prior to the tsunami. This hypothesis is corroborated by the fact that several deep sea fishes were caught near the sea surface hours before the tsunami.

153. Nishimura, G. and Takayama, T.

1934 Experimental study of the propagation of tsunami waves. Bulletin of the Earthquake Research Institute, Tokyo Imperial University, Supplementary. 1:232-271.

Based on data recorded during the Sanriku tsunami of 1933, a model experiment was carried out to determine the effects of coast topography and configuration of the sea bottom on the propagation of tsunamis. The experiment was carried out in a wooden tank in which several types of bays were simulated. The propagation of a long solitary wave (representing the tsunami) in the following types of bays were studied:

(a) Bay of rectangular cross section and uniform depth,
(b) Triangular bay of uniform depth, and
(c) Bay of rectangular cross section, whose depth decreases uniformly.

Based on these tests new formulas for computing the wave velocity (inside bays), rate of increase of wave heights, and maximum velocity of surface water particles were developed.

154. Nakamura, S. T.

1934 The geophysical observations of the tsunami of March 3, 1933. Ziho Saito Ho-on Kai (Ziho Saito Gratitude Foundation), Reprint Series. No. 88, pp. 1-12.

By analyzing seismological, magnetic, and electrical data recorded at Mukaiyama Observatory (Sendai, Japan) during the Sanriku earthquake and tsunami of March 1933, the following conclusions were reached:

(a) The magnetic dip at Sendai (and in general all over the eastern part of North Japan) had increased gradually since August 1932, until it had reached a maximum about two months before the occurrence of the tsunami,

(b) After the tsunami, the secular change of magnetic dip recovered its general tendency of gradually decreasing,

(c) A similar change of the magnetic dip (but of the opposite sign) was observed before the Sanriku tsunami of 1896 by the Hydrographical Department of the Japanese Navy, and

(d) The disturbance of the earth's potential was not very noticeable, but since the end of February 1933 irregular changes were being observed.

155. Matuzawa, T.

1934 Comparison of movement of water in a V-shaped bay with that in a U-shaped bay. National Research Council of Japan, Japanese Journal of Astronomy and Geophysics, Tokyo. 11(2):67-78.

Experience gained from previous tsunamis has shown that they cause more destruction in V-shaped bays opening directly towards the ocean than in bays of other types. To confirm this theory the destruction caused by the Sanriku tsunami of March 1933 at Aneyoshi is described. In the inner end of this bay the tsunami reached a height of 21 meters, while at the mouth of the bay it reached only 13 meters. By treating the V-shaped bay as an equilateral trapezoidal bay whose depth decreases uniformly and using the data recorded at Aneyoshi, a mathematical computation was developed in order to establish:

(a) The ratio of tsunami height at any point of the bay to that at the inner end of the bay, and

(b) The velocity of the horizontal flow at any point of the bay. The results obtained from these computations were compared with data recorded at U-shaped bays, it being concluded that for the same conditions of water movement at the mouth of the bay, the movement of the water develops more violently in a V-shaped bay than in a U-shaped one.

156. Imamura, A.

1934 Past tsunamis of the Sanriku coast. National Research Council of Japan, Japanese Journal of Astronomy and Geophysics. 11(2):79-93.

The largest tsunamis observed in the Sanriku district (northeast Japan) during the period 869-1933 were studied comparatively, it being concluded that they occurred almost contemporaneously with seismic activities in the Kwanto district. This fact is explained by taking into consideration that the Kwanto earthquakes and the Sanriku tsunamis are caused by crustal deformations occurring along the circum-Pacific seismic zone. It is also pointed out that during the Sanriku tsunamis of 1894, 1896 and 1933, small undulations of the sea level were observed a few hours prior to the arrival of the tsunami itself. This fact would suggest that crustal deformations of secondary magnitude took place some hours before the main dislocation of the sea bed.

157. Matuyama, M.

1935 Measurements of gravity over the Japan Trench. Chikyu (The Globe). 23:1-12. (In Japanese)

By considering that the submarine earthquakes which had caused severe tsunamis on the Pacific coast of northeast Japan had their epicenters in the Japan Trench, careful gravity measurements were made in this area as a first step for a study of its geological and geophysical features. The preliminary work showed that:

(a) There is a positive vertical deflection zone along the shore,

(b) A zone of negative anomalies (negative vertical deflections) was found along the western slope of the trench, and

(c) Most of the tsunamis studied were produced by earthquakes centering on the zone of negative anomalies.

158. Suzuki, T.

1935 Seiche in the Tokyo Bay caused by the land upheaval on the occasion of the great earthquake of September 1, 1923. Bulletin of the Earthquake Research Institute, Tokyo Imperial University. 13:266-279.

Marigrams recorded during the Kwanto tsunami of September 1923 at Yokosuka and Chiba (stations which are situated at opposite sides of the Tokyo Kaiwan) showed that the waves, which were produced apparently by vertical displacements of the bed of Sagami Nada, were relatively small in Tokyo Kaiwan. By considering that both bays are joined by the short and narrow Uraga Suido, it was necessary to assume that, due to their different depths (Sagami being deeper), only a small part of the tsunami was able to cross the channel. The marigraphic analysis also showed that in addition to the permanent upheavals of the sea bed shown by the sounding surveys (see No. 102), temporary upheavals took place during the earthquake preceding the tsunami.

159. Nakano, N. and Nakagawa, J.

1935 On the path of propagation of sea waves originated by earthquakes. The Geophysical Magazine, Tokyo. 9:215-221.

By assuming the location of the tsunami center is known, a general discussion of the methods for tracing the path of propagation of tsunamis is made. By considering the velocity of tsunami propagation to be $V = \sqrt{gH}$ and accepting Terada's theory that the time taken by the wave in propagating between 2 points is a minimum, the equation of the tsunami path was established. This equation was applied to studying the propagation of the Sanriku tsunami of March 1933. In this study the marigrams recorded at Tsukihama during the tsunami were used and the coincidence of the quake epicenter and tsunami center was assumed.

160. Neumann, F.

1935 Tidal observations. United States Earthquakes 1933, U.S. Coast and Geodetic Survey, Serial No. 579, Washington, D. C., p. 24.

According to marigrams registered at Honolulu and Santa Monica, California, the great Sanriku tsunami of March 1933 propagated toward these ports with average speeds of 480 and 475 miles per hour, respectively. In Hawaiian ports the waves reached maximum heights of 9.5 feet while in California they were perceptible only to the marigraphs.

161. Fukutomi, T.

1936 Heights of tsunamis at Simoda in southern Idu peninsula. Bulletin of the Earthquake Research Institute, Tokyo Imperial University. 14:68-74. (In Japanese)

In the last 5 centuries the port of Shimoda (southern Idu peninsula) had been devastated by 7 tsunamis of seismic origin and 2 tsunamis due to meteorological causes (typhoons). The mean and maximum heights reached by the water at Shimoda during these tsunamis are tabulated in this paper. It is indicated that the epicenters of the earthquakes which caused the seismic tsunamis are distributed over a great area in the outer zone of the Japan arc.

162. Heck, N. H.

1936 Earthquakes. Princeton University Press. Chapters II and IX.

A study of tsunamis, based principally on the Japanese reports of the Sanriku tsunami of March 1923, showed that they are caused by vertical displacements of the sea bottom and that such displacements are produced only by earthquakes of suboceanic foci. It is also pointed out that strong undersea earthquakes, even without producing vertical displacements of the sea bed, can set up important vibrations of the water and consequently small disturbances of the sea surface. In regard to the coastal slope, it is indicated that destruction caused by tsunamis would be important only on flat shores, but would be negligible on steep shores. Finally, a brief description of the largest tsunamis recorded is added.

163. Davison, C.

1936 Great earthquakes. Thomas Murby & Company, London.

A very complete description of some of the greatest earthquakes of the last two centuries is given. Of these earthquakes, the following ones were accompanied by tsunamis: Lisbon (1755 and 1761), Calabria (1783, 1894, and 1905), Valparaiso (1822 and 1906), Concepcion (1835), Sanriku (1896 and 1933), Yakutat Bay (1899), Messina-Calabria (1908), and Tango (1927). The description of these tsunamis includes data regarding heights reached by the water at several ports located in the affected area, damage caused to these ports, velocity of propagation of the waves, and distance traveled by them.

164. Imamura, A.

1937 Theoretical and applied seismology. Manzen Co. Tokyo. Chapter VI.

Tsunamis have their origin in vertical displacements of the sea bed occurring during undersea earthquakes, or in submarine volcanic eruptions. The outstanding features of their waves are great length and relatively small amplitude. Due to these characteristics the energy of tsunami waves does not decrease as rapidly as in ordinary wind waves. The wave amplitude increases gradually when the tsunami approaches the coast, reaching enormous heights in some special bays, mainly V-shaped bays. Based on data recorded during the tsunamis of Sanriku (1896) and Osaka (1631), a study of the means of mitigating the destruction caused by tsunamis is carried out and the efficiency of the usual structure of harbor protection against tsunamis is analyzed.

165. Otuka, Y.

1939 On the earthquake that occurred in November 1938 on the Pacific coast of northeast Japan. Bulletin of the Earthquake Research Institute, Tokyo Imperial University. 17:168-178. (In Japanese)

On 5 November 1938, a small earthquake centering off the northeast coast of Japan was accompanied by a relatively destructive tsunami. The marigrams recorded at Japanese tidal stations showed two groups of regular waves, followed by a somewhat irregular motion lasting for several hours. The most noteworthy fact observed was that some of the aftershocks were accompanied by tsunamis of secondary magnitude, suggesting that small landslides in the sea bed took place simultaneously with such aftershocks.

166. Gutenberg, B.

1939 Tsunamis and earthquakes. Bulletin of the Seismological Society of America. 29:516-526.

The hypothesis that the largest tsunamis observed have been produced by submarine landslides is advanced. Seismic disturbances would act as a trigger for setting the slides in motion. This hypothesis is corroborated by quoting the works of Milne, Montessus de Ballore, and others and referring to data obtained during major tsunamis. It is also indicated that tectonic movements of the sea bottom would produce only relatively small tsunamis. A final verification is obtained by a detailed study of the Atacama tsunami of 1922. A map of the affected area, including isoseismal lines and showing the locations of the quake epicenter and tsunami center, is added to prove that the earthquake which accompanied the tsunami was entirely centered on the land. Based on the assembled data, it is shown that the Atacama tsunami was undoubtedly produced by slides of the sea bed.

167. Imamura, A. and Moriya, M.

1939 Marigraphic observations of tsunamis in Japan during the period from 1894 to 1924. National Research Council of Japan, Japanese Journal of Astronomy and Geophysics, Tokyo. 17(1):119-140.

A study of tsunamis of seismic and meteorological origin recorded at Japanese tidal stations during the period 1894-1924 was made.

(a) Tsunamis of Seismic Origin - The earthquakes preceding these tsunamis are described and the marigraphic data recorded during the phenomena are discussed. From this study it was concluded that: (1) Tsunamis associated with non-regional earthquakes have smaller periods and relatively shorter duration compared with those associated with quakes centering near the observing station, and 2) the influence of the coastal topography seems to be stronger in the case of tsunamis associated with non-regional earthquakes; and

(b) Tsunamis of Meteorological Origin - These are due mainly to cyclonic storms and present different characteristics from those of seismic origin. However, the periods of the oscillations they produced in bays resemble those of the undulations generated by tsunamis accompanying non-regional earthquakes.

168. Kishinouye, F. and Iida K.

1939 The tsunami that accompanied the Oga earthquake of May 1, 1939. Bulletin of the Earthquake Research Institute, Tokyo Imperial University. 17:733-740.

By applying the Miyabe method (see No. 148) to marigrams recorded at Japanese stations during the Oga tsunami (Japan Sea) of 1 May 1939, the geographical position of the tsunami center was determined. It was found that the tsunami source was not a point but a rather large area.

169. Platania, G.

1940 I Maremoti nel Golfo Di Napoli. Annali dei Lavori Pubblici. Roma. 78:584-588. (In Italian)

During important tsunamis, the following types of waves had been observed:

(a) Compressional (or condensational or longitudinal) waves are produced either by subcontinental or suboceanic earthquakes and are perceptible only in the immediate neighborhood of the earthquake epicenter,

(b) Gravitational (or distortional or transversal) waves accompany suboceanic earthquakes exclusively and propagate to great distance over the oceans, and

(c) Stationary waves are either of seismic or meteorological origin.

According to Mallandra (see No. 130) the eruptions of Vesuvius are usually accompanied by tidal disturbances. However, a study of such disturbances has shown that not all of them can be considered real tsunamis. It is believed that the tsunamis were caused by earth shocks accompanying the eruptions and not by the eruptions themselves.

170. Neumann, F.

1940 United States earthquakes 1938, U. S. Coast and Geodetic Survey, Serial No. 629, Washington, D. C. p. 33.

During 1938 the following tsunamis were registered:

(a) Tsunami originating in the Solomon Islands and recorded at Honolulu;

(b) Tsunami centering on the Queen Charlotte Islands, recorded at Santa Monica, California;

(c) Tsunami associated with an earthquake centering on 1°N, 119°E., recorded at Santa Monica, California; and

(d) Tsunami associated with a submarine earthquake centering off the southern coast of the Alaskan Peninsula.

Some information concerning the tsunamis is given and copies of the marigrams recorded at Honolulu, Alaska, and the West Coast of the U.S.A. during the Alaskan tsunami are annexed.

171. Miyabe, N.

1941 Tsunami associated with the earthquake of August 1940 Bulletin of the Earthquake Research Institute, Tokyo Imperial University, 19:104-114. (In Japanese with English summary)

A brief description of the Hokkaido tsunami (Japan Sea) of 2 August 1940 is given and the geographical position of the tsunami center is determined by using the Miyabe method (see Nos. 148 and 168). It was found that the tsunami center was a rather large area and that the earthquake epicenter lay within such area. Marigrams recorded at various places along the coast of Hokkaido were analyzed and the effect of slope and shape of the bays upon tsunami propagation was studied.

172. Bodle, R. R.

1944 Tidal disturbances of seismic origin. United States Earthquakes 1942, U. S. Coast and Geodetic Survey, Serial No. 662, Washington, D. C. p. 17.

On 27 August 1942 an earthquake centering near Pisco (Peru) was accompanied by a tsunami which propagated along the Peruvian coast, being recorded at Matarani (230 miles southeast of the quake epicenter) and Callao (220 miles northwest of the quake epicenter). This tsunami probably resulted from one or more submarine slides caused by the earthquake and according to the data recorded at Matarani and Callao its center did not coincide with the earthquake epicenter. Due to difficulties in determining the center and paths of propagation of the tsunami, the velocities of propagation of the waves could not be computed accurately.

173. Bodle, R. R.

1945 Tidal disturbances of seismic origin. United States

Earthquakes of 1943, U. S. Coast and Geodetic Survey, Serial No. 672, Washington, D. C.

On 6 April 1943 a strong earthquake centering on Norte Chico (Chile) was accompanied by a tsunami which was observed at several ports on the epicentral area and was recorded by the marigraph at Valparaiso, located about 100 miles southwest of the epicenter. Copy of marigram is annexed.

174.

1945 Earthquake in the Arabian Sea. Nature, London. 156:712-713.

The strong submarine earthquake of 27 November 1945 in the Arabian Sea was accompanied by a destructive tsunami which was especially severe on the coast of Makran (northwest of Karachi) and caused damage in Bombay 1,500 kilometers from the quake epicenter. The occurrence of important sea bed dislocations during the earthquake was confirmed by the appearance of two new islands in the Arabian Sea.

175

1945 Earthquake in the Arabian Sea. Earthquake Notes, Eastern Section of the Seismological Society of America. 17(1 & 2):10.

The Arabian Sea earthquake of November 1945 centering about 180 miles from Karachi was accompanied by a tremendous tsunami which swept the coast of Makran reaching as far as Bombay, where it caused heavy loss of life and property.

176. Rothe, J.

1946 Le seisme de 27 novembre 1945 et l'hypothese de Suess sur la cause du deluge. Comptes Rendus de l'Academie des Sciences Paris. 222:301-302. (In French)

In 1897, E. Suess (see No. 52) advanced the idea that the legend of the "Deluge" was based on the occurrence of a violent tsunami which had inundated the low Euphrates valley in pre-biblical times. This tsunami would have accompanied a destructive earthquake centering somewhere south of the Persian Gulf. The theory of Suess had been severely criticized by taking into consideration the low seismicity of the Persian Gulf area. The Arabian Sea earthquake (epicenter on the Arabian Sea at the entrance of the Persian Gulf) and tsunami of November 1945 have, in some way, justified the theory of Suess by showing that even though seismic frequency is very low in this area, the earthquake intensity can be high. In fact, the violence of the Arabian Sea earthquake, as computed by the Gutenberg-Richter method, was comparable to that of the San Francisco earthquake of 1906. On the other hand, the destructive tsunami which accompanied this earthquake would be a further proof of the Suess theory.

177. Powers, H. A.

1946 The tidal wave of April 1, 1946, The Volcano Letter, Hawaii, No. 491.

The Aleutian tsunami of April 1946 had disastrous effects on the Hawaiian Islands, which is unusual. Although these islands are frequently visited by tsunamis, the damage caused is usually small. To emphasize the point, a table listing 12 tsunamis recorded at Hawaii is included. Of these tsunamis only three caused damage which in no case was comparable to that suffered during the 1946 tsunami. In order to reduce the destruction caused by tsunamis, the establishment of a system for warning the population of the approach of dangerous tsunamis is suggested (see No. 100). This warning system would include a network of seismographs to permit the quick location of the epicenters of submarine earthquakes and a group of stations conveniently located in the Pacific to observe the propagation of the waves.

178.

1946 Seismic sea wave of April 2, 1946. Nature, London, 157:474.

The Aleutian tsunami of April 1946 originating near the island of Unimak (Aleutian archipelago) traveled through the Pacific Ocean causing great damage at the port of Hilo, located approximately 2,040 miles from Unimak. The tsunami was less strong along the California coast, but was clearly perceptible even along the coast of Chile.

179. Thornton, D. L.

1946 Seismic sea waves. Engineering, London, 161:484-485.

The Aleutian tsunami of April 1946 is described and its propagation along the Pacific coast of the Americas is studied. It is indicated that tsunamis are apparently produced by vertical displacements of the sea bed, but that further geophysical studies would be necessary before establishing a definite relation between tsunamis and changes of level of the sea bottom.

For computing the mean velocity of propagation of tsunamis, the use of the Lagrange (deep water) and Green (shallow water) formulas is suggested. By applying these formulas the velocities of propagation of the Aleutian tsunami were computed and subsequently compared with those calculated from marigraphic data recorded during the Krakatoa tsunami of 1883. The characteristics of the stationary oscillations produced in bays by the tsunami waves are also discussed, including a study of the various modes of oscillation observed at San Francisco Bay.

180. McKay, E. C.

1946 Seismic sea wave of April 1, 1946. Transactions of the American Geophysical Union, Washington, D. C. 27(3):453.

A table is given listing marigraphic data obtained at several tidal stations on Hawaii and the western coast of the Western Hemisphere during the Aleutian tsunami of April 1946. Computations of the velocities of propagation of the tsunami toward these stations and of the characteristics of the main oscillations into such bays are included.

181.

1946 Seismic sea wave velocities. The Volcano Letter, Hawaii. No. 492.

A table listing the velocities of propagation of the tsunamis of Arica (1868) and Aleutian Islands (1946) as computed by Milne and McKay, respectively.

182. Beer, A. and Stagg, J. M.

1946 Seismic sea wave of November 27, 1945. Nature, London, 158:63.

On 28 November 1945 a small tsunami was recorded at Port Victoria. It is believed that this tsunami was associated with the major earthquake which occurred some hours earlier in the Arabian Sea (see Nos. 174 and 176). By using marigraphic data recorded during the phenomenon and assuming the coincidence of the earthquake epicenter with the tsunami center, the velocity of propagation of the tsunami, average depth of the ocean traversed, and mean wave length were computed. The values thus computed were substantially smaller than those deduced from other recorded cases of seismic waves. This discrepancy is explained by considering that the first waves were not recorded at Port Victoria and that the tide gage in this bay registed only the arrival of the eighth wave.

183. Bodle, R. R.

1946 Note on the earthquake and seismic sea wave of April 1, 1946. Transactions of the American Geophysical Union, Washington, D. C., 27(4):464-465.

By using seismographic data recorded in U.S.A., Alaska, and Hawaii, the position of the epicenter and depth of the focus of the Aleutian earthquake of April 1946 were determined. Marigraphic studies of the tsunami associated with this earthquake tended to confirm the exactness of the epicentral position obtained from the seismograms.

184. Green, C. K.

1946 Seismic sea wave of April 1, 1946, as recorded on tide gages. Transactions of the American Geophysical Union, Washington, D. C., 27(4):490-500.

The Aleutian earthquake of April 1946, centered some 80 miles southeast of Unimak Island on the steep slopes of the Aleutian Trench, was accompanied by a tsunami which was registered on the west coast of U.S.A., Honolulu, Costa Rica, Peru, and Chile. The velocities of propagation of the tsunami through the Pacific calculated by applying the formula $V = \sqrt{gH}$ agreed well with those computed from the marigraphic data. Copies of several of the tide gage records used on the previous computations are given and separate analysis of them is made in order to determine the periods of the most prominent oscillations registered in the bays where the marigraphs were located.

185.

1946 The earthquake and seismic sea wave of April 1, 1946. Earthquake Notes, Eastern Section of the Seismological Society of America, 18(1 & 2):10-11.

The Aleutian tsunami of April 1946, centering about 80 miles from the Unimak Island reached heights of 90 to 100 feet in ports located in the epicentral area and hit destructively on the Hawaiian Islands, being especially severe in the port of Hilo. The tsunami propagated southward along the Pacific coast of the Americas and even though it caused negligible damage on the coast of U. S.A., it reached dangerous heights in the port of Iquique and Juan Fernandez islands.

186.

1946 Dominican Republic earthquake of August 4, 1946. Earthquake Notes, Eastern Section of the Seismological Society of America. 18(1 & 2):11-12.

On 4 August 1946 a strong earthquake centering about 10 miles off the eastern end of Samana Peninsula (Dominican Republic) generated a destructive tsunami which caused damage over a wide portion of the Dominican coast, as well as minor damage on the coast of Haiti. Marigrams of this tsunami were obtained at tidal stations on Puerto Rico.

187. Powers, H. A.

1946 The Aleutian tsunami at Hilo, Hawaii, April 1, 1946. Bulletin of the Seismological Society of America, 36(4):355-356.

The Aleutian tsunami of April 1946 was recorded at several ports in the Hawaiian Islands, being especially severe on the northeast coast of the island of Hawaii. Non-instrumental data obtained at Hilo, where the waves reached a height of 32 feet, showed that the tsunami propagated toward that port with a mean velocity of 7.9 miles per minute.

188. Bodle, R. R.

1946 Tidal disturbances of seismic origin. United States Earthquakes 1944, U. S. Coast and Geodetic Survey, Serial No. 682, Washington, D. C., p. 25.

The tsunami which accompanied the Japanese earthquake of 7 December 1944 was recorded by marigraphs at Alaska and California. Copy of the marigram obtained at Massacre Bay, Alaska, is included.

189. MacDonald, G. A., Shepard, F. P., and Cox, D. C.

1948 The tsunami of April 1, 1946 in the Hawaiian Islands. Pacific Science, University of Hawaii, January 1947, Vol. 1, No. 1. Also in the Annual Report of the Smithsonian Institution for the year 1947, Washington, D. C., pp. 257-259.

The Aleutian tsunami of April 1946 was caused by dislocations of the sea bottom on the northern slope of the Aleutian Trench and propagated southward toward the Hawaiian Islands with an average speed of 490 miles per hour, causing heavy losses of property and life. A study of the seismic history of the Hawaiian Islands showed that even though their seismic activity is rather small, they have been frequently struck by tsunamis originating on the Pacific coast of the Americas and Japan. A detailed account of the heights reached by the waves and the extent of the damage at various Hawaiian ports was assembled in order to study the influence of the coastal topography upon tsunami propagation. In order to reduce the structural damages and casualties during future tsunamis, the following protective measures are suggested:

(a) Construction of harbor protective structures, especially sea walls,

(b) Total elimination of construction at especially dangerous areas, and

(c) Establishment of a system for warning the population of the approach of tsunamis.

190. Macelwane, J. B.

1947 When the earth quakes. Bruce Publishing Company, Milwaukee.

Chapter VII of this treatise in seismology gives an analysis of actual knowledge of tsunami generation and propagation. It is indicated that tsunamis are originated by upheavals or downfalls of small areas of the sea bottom in the neighborhood of coasts. These dislocations would be produced exclusively by submarine earthquakes. The phenomenon of refraction of seismic waves in the interface land-water is studied, it being concluded that a small part of the seismic wave energy goes through the water in the form of longitudinal waves. This release of seismic energy to the water would produce small disturbances of the sea surface.

191. Heck, N. H.

1947 List of seismic sea waves. Bulletin of the Seismological Society of America. 37(4):269-286.

A catalog listing 270 tsunamis recorded all over the world during the period 479 B.C.-1946 A.D.

192. Lyinch, J. J. and Bodle, R. R.

1948 The Dominican earthquakes of August 1946. Bulletin of the Seismological Society of America. 38(1):1-17.

A detailed description of the casualty and structural damage caused by the Dominican earthquake and tsunami of August 1946 (see No. 186) is given. One of the aftershocks (8 August) following the earthquake was accompanied by a smaller tsunami.

193. Pendse, C. G.

1948 The Makran earthquake of the 28th November 1945. India Meteorological Department, Scientific Notes, Simla. 10(125):141-145.

The Arabian Sea earthquake of November 1945 centered off the Makran coast (Baluchistan) and was accompanied by a disastrous tsunami which affected the whole of the Arabian seaboard. Studies of the seismic history of the epicentral area and of the seismometric data recorded during the earthquake shows that:

(a) So far as its magnitude is concerned this earthquake was not particularly important in comparison with some great seismic shocks recorded in this area during recent years, and

(b) Tsunamis rarely accompany earthquakes centering on this area. The tsunami was caused by topographical changes occurring in the sea bed of the epicentral area. The appearance of two islets near Karachi confirmed the existence of such dislocations. The characteristics of the waves recorded at Karachi, Bombay, and ports on the Makran coast are described and information regarding the structural damage suffered by these ports is given.

194. Bodle, R. R. and Murphy, L. M.

1948 Tidal disturbances of seismic origin. United States Earthquakes 1946, U. S. Coast and Geodetic Survey, Serial No. 714, Washington, D. C., p. 23.

The largest tsunamis recorded during 1946 were those of the Aleutian archipelago (1 April) and Dominican Republic (4 and 8 August). Some data concerning the magnitude of these tsunamis are given and a table listing their velocities of propagation to various tidal stations is annexed.

195.

1948 Seismic sea wave warning system. Earthquake Notes, Eastern Section of the Seismological Society of America. 20(2):14.

Following the disastrous Aleutian tsunami of April 1946, the U. S. Coast and Geodetic Survey established a system for warning the population of the Hawaiian Islands of the approach of tsunamis (see Nos. 100 and 177). Such a warning system is based on a network of seismographs to provide information quickly about submarine eqrthquakes and a group of stations for observing the propagation of the waves. Coupled with these there is a priority communications system. To provide an easy way for evaluating the velocities of propagation of the waves, a "tsunami travel-time chart" was prepared.

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